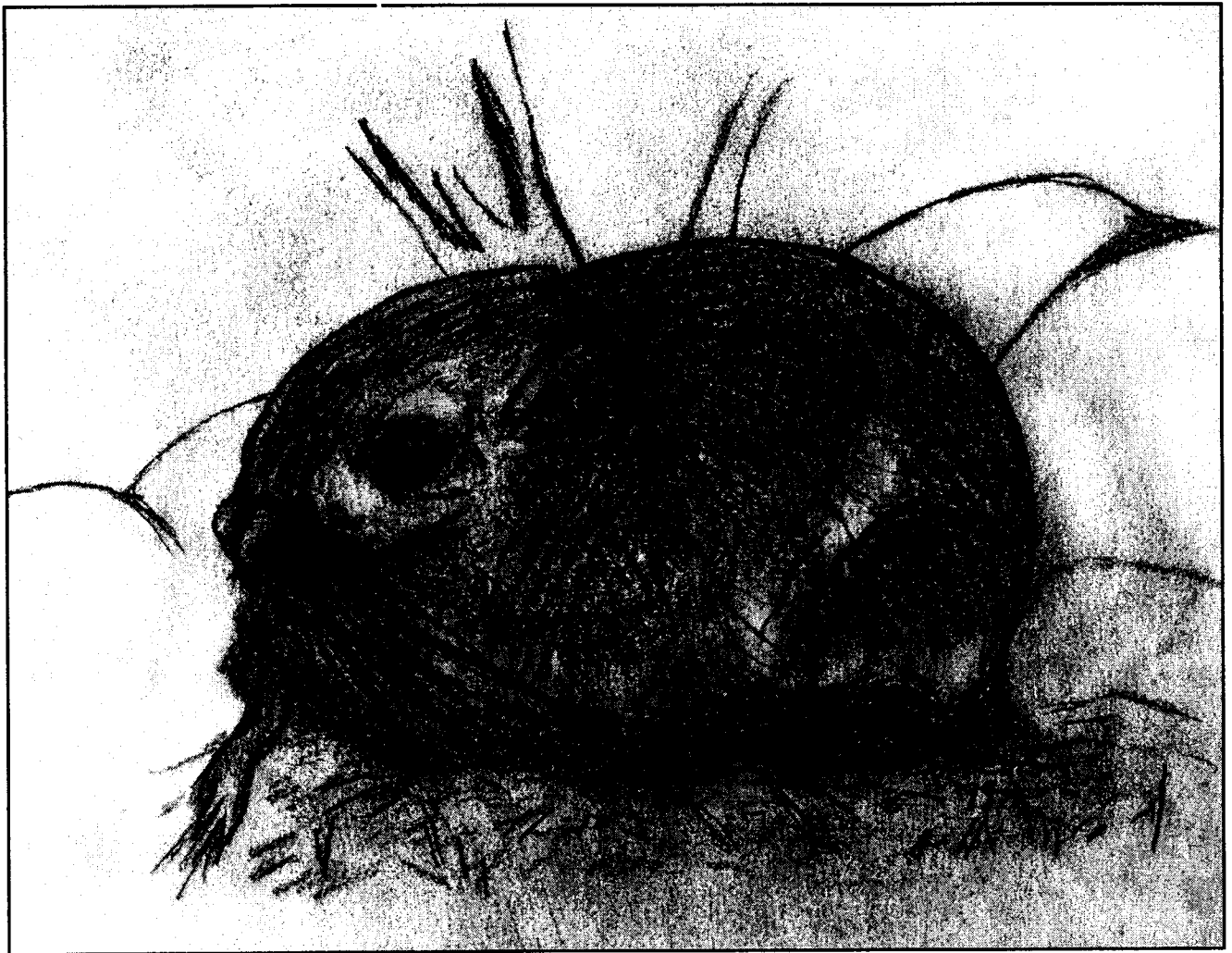


Draft Revised Recovery Plan for the Morro Bay Kangaroo Rat (*Dipodomys heermanni morroensis*)



Morro Bay Kangaroo Rat

(*Dipodomys heermanni morroensis*)

Draft Revised Recovery Plan

(September 1999)

(Original plan approved August 18, 1982)

Prepared by the Morro Bay Kangaroo Rat Recovery Team

for
Region 1
U.S. Fish and Wildlife Service
Portland, Oregon



Approved: _____XXXXXXXXXX

Manager, California/Nevada Operations Office,
Region 1, U.S. Fish and Wildlife Service

Date: _____

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The recommendations and information contained in this draft revised recovery plan represented the views of the Morro Bay kangaroo rat recovery team in 1995.

LITERATURE CITATION

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EXECUTIVE SUMMARY

Current Species Status: The Morro Bay kangaroo rat (*Dipodomys heermanni morroensis*) is listed as endangered. Historically, it occurred on approximately 10 square kilometers (4 square miles) south of Morro Bay, San Luis Obispo County, California. The most recent estimate of its range size is approximately 15 hectares (37 acres), on private land. No recent population estimates are available. However, fewer than 50 individuals likely exist. Three prior attempts at captive breeding of the Morro Bay kangaroo rat and a closely-related subspecies, the Lompoc kangaroo rat (*D. h. arenae*), have met with mixed success. Recent efforts at captive breeding the Lompoc kangaroo rat appear successful.

Habitat Requirements and Limiting Factors: The Morro Bay kangaroo rat occurs in habitat associated with stabilized sand dune, coastal dune and coastal sage scrub, and maritime chaparral communities. Sandy soils are essential for burrow construction. Threats to the Morro Bay kangaroo rat include direct loss of habitat from residential development, changes in habitat characteristics, predation from domestic animals, and fragmentation of habitat which results in higher vulnerability to extirpation from chance events.

Recovery Priority: 6C; this number reflects a high degree of threat, low potential for recovery, that this is a subspecies, and that its conservation may be in conflict with construction or development projects. Recovery priority numbers range from 1 (high degree of threat, high recovery potential) to 18.

Recovery Objective: Downlist to threatened. Delisting is not likely because the limited amount of remaining historic habitat is probably insufficient to ever remove the threat of endangerment.

Recovery Criteria: Based purely on genetic considerations, the Morro Bay kangaroo rat may be reclassified as threatened when an effective genetic population size of 500 has been achieved, which translates to an actual census size

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of about 2,000 individuals. The subspecies must have a 95 percent probability of persisting for at least 100 years. This populations size must be sustained with a mean at that level for 10 consecutive years, with adequate geographic distribution.

Assuming a mean density of 10 animals per hectare (4 animals per acre), approximately 200 hectares (500 acres) of functional habitat will be required for status improvement. If habitat is not managed to sustain a mean density of 10 animals/hectare, more land will be required. Any change in the protected status of the Morro Bay kangaroo rat should be based on the status of the subspecies in the wild.

Actions Needed:

1. Remove up to 100 Morro Bay kangaroo rats from the wild and breed them in captivity using techniques developed with a surrogate, the Lompoc kangaroo rat (*Dipodomys heermanni arenae*).
2. Identify and coordinate interagency activities to secure, manage, and improve habitat for all available areas in historic habitat.
3. Reintroduce Morro Bay kangaroo rats to the wild in restored habitat using techniques developed with the Lompoc kangaroo rat.
4. Revise the Morro Bay kangaroo rat recovery plan based on population viability analyses.
5. Conduct public outreach and fundraising efforts.

Parties Responsible for Implementation:

1. Fish and Wildlife Service
2. California Department of Fish and Game
3. California State Parks
4. University of California, Berkeley

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5. San Luis Obispo Land Conservancy
6. County of San Luis Obispo
7. Private landowners

Estimated Cost of Recovery: Due to the highly uncertain status of the Morro Bay kangaroo rat, it is not possible to estimate all recovery costs at this time. The estimated cost of recovery actions through 2004 is \$2,148,000 plus additional costs that are presently unknown.

Date of Recovery: Unknown. Without access to the private parcel believed to support the last extant population of the Morro Bay kangaroo rat, recovery efforts critical to preventing its extinction cannot commence.

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BRIEF OVERVIEW

The Morro Bay kangaroo rat (*Dipodomys heermanni morroensis*) occurs within a restricted range on stabilized sand dunes south of Morro Bay in San Luis Obispo County, California. Its survival is endangered by the continuing destruction and modification of its habitat. These threats were first recognized by Stewart (1958) and have been re-emphasized by subsequent investigators (Stewart and Roest 1960; Congdon 1971; Congdon and Roest 1975; Roest 1973, 1977, 1982, 1984; Toyoshima 1983; Gambs 1985, 1986a, 1986b, 1986c, 1986d, 1986e, 1986f, 1986g, Gambs and Holland 1988; Gambs and Nelson 1989 and 1990; Villablanca 1986, 1987). The Morro Bay kangaroo rat was listed as a Federal endangered species in 1970 (Federal Register 35 [199]: 16047), and was recognized as an endangered species by the State of California in 1971. In 1971 it was also listed in the International Red Data Book for Mammals (Int. Union Cons. Nat. 1971). Critical habitat (see figure 2) was designated for this species in 1977 (Federal Register 42 [184]: 40685 and 17840). The last remaining Morro Bay kangaroo rats are thought to reside on privately-owned lands. Access by Federal and State biologists to some parcels has been prohibited since 1986. However, there appears to be potential for purchasing privately-owned habitat.

Since the original recovery plan for the Morro Bay kangaroo rat was approved (Fish and Wildlife Service 1982), the status of the Morro Bay kangaroo rat and its habitat has not improved. The original recovery plan is being revised because it did not specifically provide for recovery actions that were deemed necessary after its approval. The revised recovery plan provides (1) a critical evaluation of the present status of this endangered species, (2) an evaluation of additional recovery options, and (3) a description of the level of recovery that is possible for the species. The revised recovery plan places a high priority on funding implementation of the few, remaining recovery options.

This revised recovery plan updates the background provided in the 1982 plan and outlines a program that, if implemented immediately, could prevent extinction of this endangered animal and eventually lead to its reclassification as a threatened species.

I. INTRODUCTION

A. Taxonomy and Description

The Morro Bay kangaroo rat is 1 of 19 species of kangaroo rats (genus *Dipodomys*) within the family Heteromyidae. This family is related to squirrels rather than to rats and mice, and thus belongs in the superfamily Sciuroidea. The genus *Dipodomys* occurs only in the warmer, more arid portions of the North American continent (Grinnell 1922). All species of *Dipodomys* are similar, even down to small details of external structure (Grinnell 1922). All the kangaroo rats have external cheek pouches, large hind legs, relatively small front legs, long tails, and large heads. The appendix to this recovery plan provides a technical review of the systematics of the Morro Bay kangaroo rat.

Heermann's kangaroo rat (*Dipodomys heermanni*), 1 of 12 species with 5 clawed-toes on the hind foot, is similar in size and general appearance to 2 other species of kangaroo rats with ranges contiguous to that of *D. heermanni*, *D. agilis* and *D. venustus*, and 2 noncontiguous species, *D. stephensi* and *D. gravipes* (Williams et al. 1993).

The species *Dipodomys heermanni* includes nine subspecies: *D. h. arenae*, *berkeleyensis*, *dixonii*, *goldmani*, *heermanni*, *jolonensis*, *morroensis*, *swarthi*, and *tularensis*. They inhabit the inland valleys and coastal plains of California from south of the American River on the east and the Suisun Bay on the west, southward, below 900 meters (3,000 feet) elevation to Point Conception and the Tehachapi Mountains (Kelt 1988, Williams et al. 1993) (Figure 1).

The Morro Bay kangaroo rat is smaller and more darkly-colored than the most similar subspecies of *D. heermanni* (Appendix 2). Merriam (1907) considered these differences to be significant enough to warrant full species status for the Morro Bay animals, which he described as *Perodipus morroensis*. Grinnell (1922) supported this recognition, but revised the name to *Dipodomys morroensis*. Boulware (1943) however, noted its resemblance to Heermann's kangaroo rat, and renamed it as a subspecies of that species, *Dipodomys heermanni morroensis*.

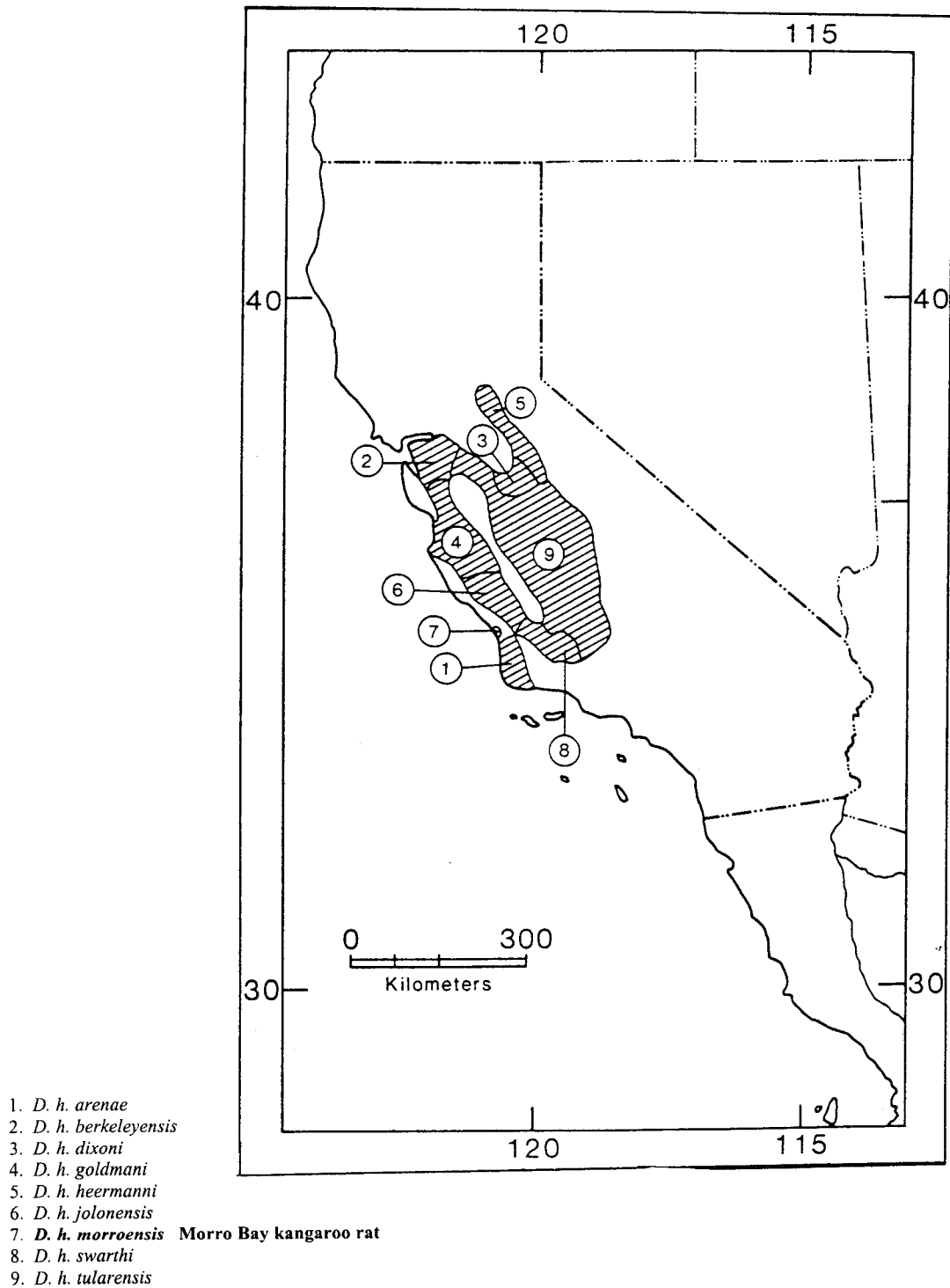


Figure 1. Distribution of Heermann's kangaroo rat (*Dipodomys heermanni*).
Source: Kelt, Amer. Soc. Mamm. (1988).

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Other more recent studies have confirmed its distinctive features and its relationship to *D. heermanni* (Risser 1975, 1976; Roest 1984).

The Morro Bay kangaroo rat is completely isolated from other subspecies of *Dipodomys heermanni*. Souza (1958a, 1958b) found the nearest populations of *D. h. arenae* about 23 kilometers (14 miles) southeast and 1.6 kilometers (1 mile) west of Edna, where an isolated colony occupies about 140 hectares (350 acres). *D. h. jolonensis* ranges to within roughly 27 kilometers (17 miles) of the range of *D. h. morroensis*. *D. h. swarthi*, which only occurs in the eastern part of San Luis Obispo County, is separated from *D. h. morroensis* by over 64 kilometers (40 miles).

B. Distribution and Abundance

Grinnell (1922) first described the range of the Morro Bay kangaroo rat (Figure 2) as an area “less than 4 miles square” near Morro Bay. He probably meant an area of less than 4 square miles, rather than an area 4 miles on each side, or 16 square miles (26 square kilometers). Grinnell described a vertical distribution for the Morro Bay kangaroo rat from sea level to an elevation of about 75 meters (250 feet).

Stewart (1958) made a careful study of the distributional limits of *D. h. morroensis*. He found Morro Bay kangaroo rats dispersed over a total area of 12.4 square kilometers (4.8 square miles), of which 5.7 square kilometers (2.2 square miles) were actually occupied by the animals. The rest of the area was covered with unsuitable habitat (oak and eucalyptus groves, thick chaparral, riparian vegetation, etc.), or was urbanized. He also found Morro Bay kangaroo rats near the 300-meter (1,000-foot) summit of a nearby, unnamed hill.

By 1971, Congdon (1971) and Congdon and Roest (1975) estimated that the total occupied range for the Morro Bay kangaroo rat consisted of about 74 hectares (183 acres) distributed over parts of six separate localities (Figure 3, Tables 1 and 2).

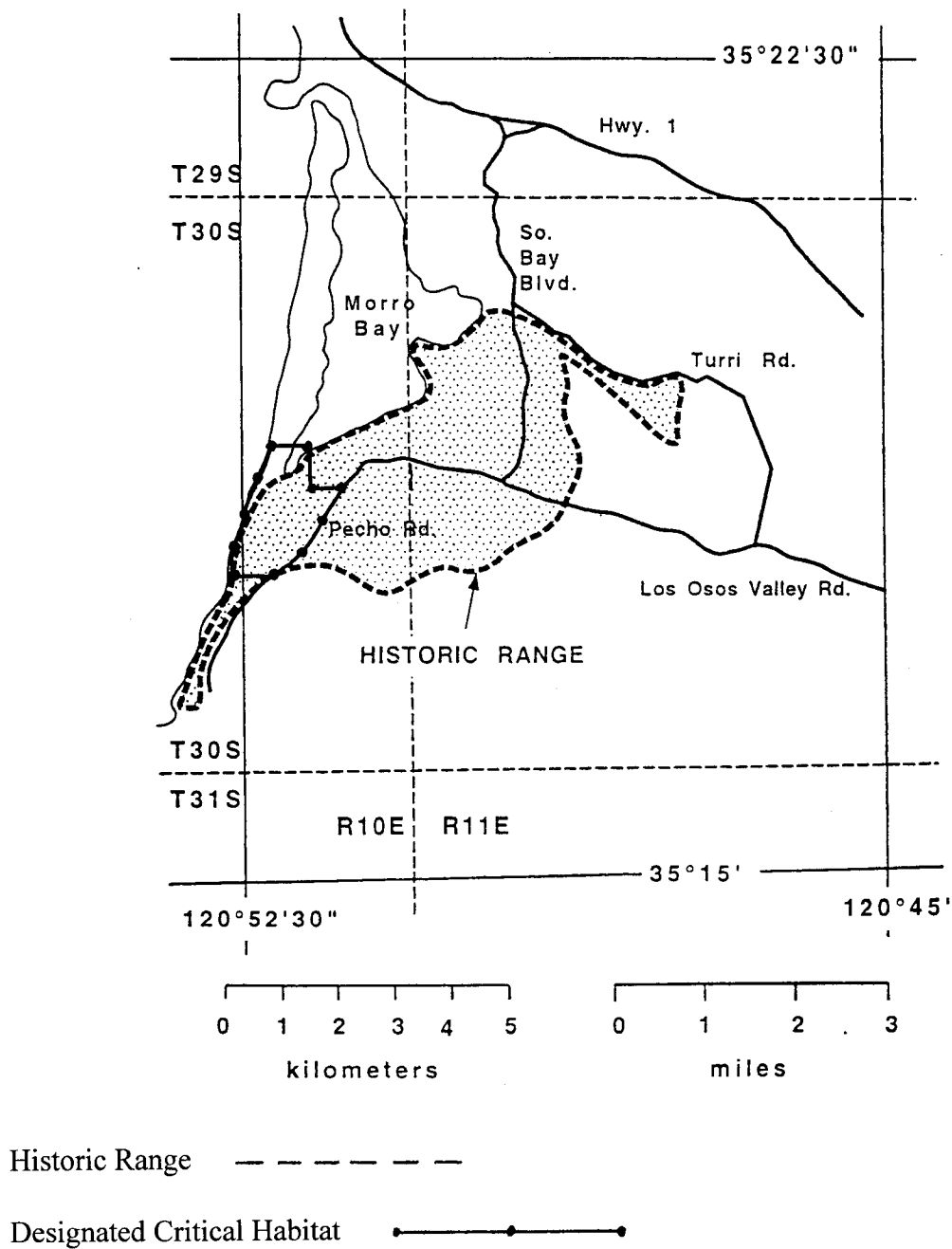


Figure 2. Historical distribution of the Morro Bay kangaroo rat (*Dipodomys heermanni morroensis*) based on information provided by Dixon (1918), Grinnell (1922), Stewart (1958), and Stewart and Roest (1960).

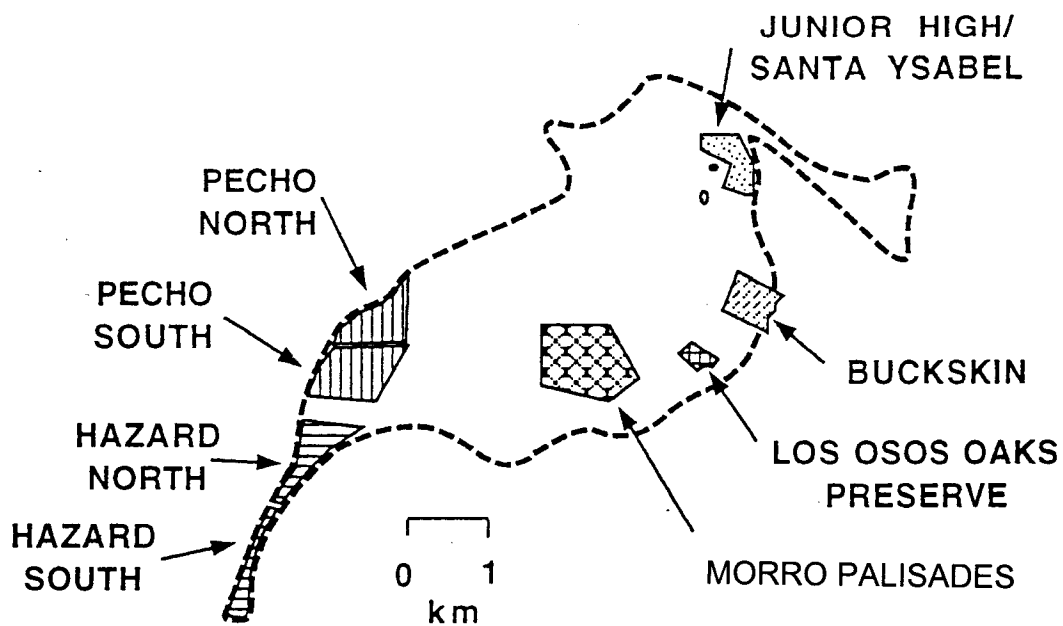


Figure 3. Location of six disjunct sites within the historic range of the Morro Bay kangaroo rat that were at least partly occupied by animals in 1971. Adapted from information provided by Congdon (1971), Congdon and Roest (1975), and Gambs et al. (1992)

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Table 1. Total area and land ownership for the six sites shown in Figure 3.

LOCALITY	TOTAL AREA		PUBLIC AREA		PRIVATE AREA	
	hectares	(acres)*	hectares	(acres)	hectares	(acres)
Morro Palisades	82.6	(204.0)	0		82.6	(204.0)
Los Osos Oaks	1.3	(3.3)	1.3	(3.3)	0	
Buckskin	22.4	(55.3)	0		22.4	(55.3)
Jr. High/ Santa Ysabel	24.0	(59.4)	0		24.0	(59.4)
Pecho North	22.9	(56.7)	22.9	(56.7)	0	
Pecho South	52.3	(129.2)	52.3	(129.2)	0	
Hazard North	16.2	(40.1)	16.2	(40.1)	0	
Hazard South	27.7	(68.5)	27.7	(68.5)	0	
TOTALS	249.4	(616.5)	120.4	(297.8)	129.0	(318.7)

*1 hectare = 2.47 acres

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Table 2. Estimates of total occupied range, total population size, and average density of Morro Bay kangaroo rats from 1957 to 1991.

YEAR	ESTIMATED OCCUPIED RANGE hectares (acres)	ESTIMATED POPULATION SIZE	AVERAGE DENSITY (Morro Bay kangaroo rats per hectare)	AUTHORITY
1957	567 (1,400)	8,000	14.1/ha	Stewart 1958 and Stewart and Roest 1960
1971	453 (1,119)	3,000	6.6/ha	Congdon 1971 Congdon and Roest 1975
1977	135 (333)	1,270-1,470	9.4-10.99/ha	Roest 1977
1978-79	127 (314)	300-1,180	2.4-9.3/ha	Toyoshima 1983
1980-83	No Data	No Data	No Data	
1984	14.2 (35.1)	21	1.5/ha	Gambs 1986a
1985	13.3 (32.9)	51	3.8/ha	Gambs 1986a
1985	13.3 (32.9)	50-150	0.7-5.8/ha	Villablanca 1987
1986	12.6 (31.1)	50	4.0/ha	Gambs 1986b
1987-88	No Data	No Data	No Data	
1989	14.8 (36.6)	No Data	No Data	Gambs and Nelson 1990
1990-91	*			

* Morro Bay kangaroo rats were present, but the number of animals and the extent of occupied range were not estimated.

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Since 1971, the populations of Morro Bay kangaroo rats at five of six disjunct sites have disappeared. Morro Palisades is the only site likely to still harbor this species. The synopsis below provides an overview of the past and present status of animals on each site.

Morro Palisades: Studies at Morro Palisades suggest that it has been continually occupied by Morro Bay kangaroo rats since at least 1957/58. Trapping and burrow survey studies conducted in 1971, 1975, 1977, 1978/79, 1984/85/86, and 1989 (anecdotal information) have consistently detected Morro Bay kangaroo rats at Morro Palisades (Table 2). The most recent population estimates, based upon live trapping in 1986, indicated that no more than 12.6 hectares (31.1 acres) of habitat on this site were populated by Morro Bay kangaroo rats at an average density of 4.0 ± 0.9 Morro Bay kangaroo rats per hectare (1.6 ± 0.94 rats per acre). Recent burrow surveys conducted at Morro Palisades indicate that no more than 15 hectares (37 acres) were occupied in 1989. No surveys have been conducted since this time. However, the draft Environmental Report for the proposed Los Osos wastewater treatment facility indicated the presence of “tail drags”, a diagnostic sign, on this site.

Los Osos Oaks State Preserve: This site is fairly close to the collection locality of specimens used by Dixon (1918) and Grinnell (1922). Los Osos Oaks was known to be occupied by Morro Bay kangaroo rats in 1918, 1957/58, 1990, and 1991 (Table 2). No signs were found there in 1971, 1975, 1977, 1978/79, or 1985. The last time that a wild-reared Morro Bay kangaroo rat was live-trapped at or near the Los Osos Oaks site was in 1957-58. The estimated area of habitat occupied by Morro Bay kangaroo rats at the Los Osos Oaks site in 1991 was 1 hectare (2.5 acres).

Buckskin: Trapping and burrow survey studies conducted in 1957/58, 1971, 1975, 1977, 1978/79, and 1985 (Table 2), have detected Morro Bay kangaroo rats at Buckskin. The most recent population estimate, based upon live trapping in 1985, revealed that no more than 0.7 hectare (1.7 acres) was populated by Morro Bay kangaroo rats at an average density of

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three Morro Bay kangaroo rats per hectare (1.2 rats per acre). No solid evidence of their presence has been found since 1985, although a focal aggregation of possible Morro Bay kangaroo rat signs near this site was reported to the San Luis Obispo County Environmental Coordinator in 1990. No Morro Bay kangaroo rat individuals or sign were detected at this site during visual and trapping surveys conducted in 1996 and 1997.

Junior High/Santa Ysabel (eastern): Studies at the Junior High/Santa Ysabel site suggest that much of the area was occupied by Morro Bay kangaroo rats until the late 1970's or early 1980's. The most recent population estimates, based upon live trapping in 1978 and 1979, revealed that no more than 6.1 hectares (15.1 acres) of habitat at the Junior High site and 10.5 hectares (25.9 acres) of habitat at the Santa Ysabel site were populated by Morro Bay kangaroo rats at average densities of 7.1 and 4.0 Morro Bay kangaroo rats per hectare (2.8 and 1.4 rats per acre), respectively (Toyoshima 1983). The last trapping record in the area was one individual trapped in 1984. Trapping and burrow survey studies conducted in 1985 failed to indicate solid evidence of their presence, although a small focal aggregation of Morro Bay kangaroo rat signs near this site was reported to the San Luis Obispo County Environmental Coordinator in 1990. No Morro Bay kangaroo rats or sign were detected during visual and trapping surveys conducted on nearby private lands in 1995, 1996, and 1997.

Pecho North: Previous studies at Pecho North indicate that much of the area was occupied by the Morro Bay kangaroo rat until about the early to mid-1970's. During the most recent trapping study of resident, wild-reared Morro Bay kangaroo rats at Pecho North (also referred to as Dunes), Roest (1977) captured 1 individual during 480 trap nights of effort. Burrow surveys and live trapping conducted at Pecho North in 1989 and 1991 failed to provide any evidence that Morro Bay kangaroo rats were present in the area. No Morro Bay kangaroo rats or sign were detected during visual and trapping surveys conducted in 1996 and 1997.

Pecho South: Like Pecho North, Pecho South was occupied by Morro Bay kangaroo rats until about the early to mid-1970's. The most recent population estimate of resident, wild-reared Morro Bay kangaroo rats at Pecho South (also referred to as Dunes) was conducted in 1978 and 1979 by Toyoshima (1983). She estimated that no more than about 20 hectares (50 acres) of Pecho South habitat were populated by Morro Bay kangaroo rats at an average density of 1.0 Morro Bay kangaroo rat per hectare (2.5 rats per acre). A focal aggregation of probable Morro Bay kangaroo rat signs was found in the fall of 1982, but none of the burrows showed signs of use the following spring. Four Morro Bay kangaroo rats from the captive breeding colony were released into an enclosure at Pecho South in 1988. One of these animals was never recaptured, but the other three were captured repeatedly in the enclosure throughout the summer and early fall of 1988. Late in the fall of 1988, one of the three animals in the enclosure escaped and established a burrow system outside the enclosure. Since then, despite intense ground surveys and trapping in the vicinity of the enclosure as well as throughout the Pecho South area in 1989 and 1991, no evidence has been found of these or other Morro Bay kangaroo rats.

Hazard North: Although parts of the Hazard North site appear to have suitable habitat, studies have never reported Morro Bay kangaroo rats or their signs from this site. A burrow survey in 1991 failed to indicate the presence of Morro Bay kangaroo rats at Hazard North.

Hazard South: The last time that a wild-reared Morro Bay kangaroo rat was trapped at the Hazard South site was in 1957-58. Solid evidence that Morro Bay kangaroo rats were still present at Hazard South was last reported in 1971; however a small, focal aggregation of Morro Bay kangaroo rat signs located in the southern part of Hazard South was reported in 1977 (Glen Stewart, personal communication to A. I. Roest). A burrow survey in 1991 failed to indicate solid evidence of Morro Bay kangaroo rats at Hazard South.

C. Physiography and Geologic History

During the late Pleistocene, about 10,000 years ago, a major sand dune formation developed on the western portion of the Los Osos Valley and a sand sheet moved inland to cover the southern flank of the valley to elevations of over 270 meters (900 feet) on the hillsides as far east as Los Osos Creek (Holland and Keil 1986b). The areas of the Los Osos Valley covered by the sand dune/sheet complex have developed very similar edaphic (soil) and vegetation patterns and Morro Bay kangaroo rats probably became established over much of the stabilized sandy soil.

D. Soils

Most of the area is covered by Baywood fine sand, a soil that supports a mosaic of coastal dune scrub, chaparral, and coastal oak woodland plant communities. The historic and potential range of Morro Bay kangaroo rats occurs almost entirely within this soil and its vegetation mosaic.

The upland area of the Irish Hills is composed of Santa Lucia shaley clay loam and is covered mostly by chaparral, although coastal oak woodland and coastal dune scrub also are present. The eastern portions of the valley, inland from the coastal dune complex, are characterized by finer textured, alluvial soils such as Salinas silty clay loam and Clear Lake clay. The natural vegetation of these areas is grassland, but much of the land is now used for agriculture. For the most part, these areas do not appear to be part of the historic or potential range of Morro Bay kangaroo rats.

E. Soil Temperature and Burrow Construction

Thermal gradients in soil temperature at 10, 30, and 60 centimeters (4, 12, and 24 inches, respectively) through the year show some interesting patterns (Gambs and Nelson 1989 and 1990). From April through August, median monthly soil temperatures at 10 centimeters (4 inches) exceeded those at 60 centimeters (24 inches). From September through February, median soil temperature is coolest at the 10-centimeter (4-inch) level and warmest at the 60-centimeter (24-inch) level.

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Thermal “turnovers” separating the two soil temperature regimes occur between March and April and again between August and September.

Morro Bay kangaroo rats and other burrowing animals probably take advantage of the annual and diurnal oscillations of soil temperature (French 1993). The “damping” effect on temperature oscillations with increasing depth creates a more stable thermal environment in deeper burrows. This relationship combined with the “turnover” phenomena should reduce the risks from summer heat stress and dehydration and winter cold stress when animals are at depths of about 60 centimeters (24 inches).

Burrows constructed in the spring and summer tend to be shallow, about 30 centimeters (12 inches) deep (Fish and Wildlife Service 1982), while burrows constructed in the fall and winter may reach depths of 80 centimeters (31 inches) or more and have a nest at a depth of 90 centimeters (38 inches) or more (Gambs and Nelson 1989 and 1990). Side tunnels may end in seed caches, open to other surface entrances, or end blindly. These results suggest that Morro Bay kangaroo rats are capable of moving to soil depths where diurnal temperature oscillations are nearly constant and minimum winter temperatures are most favorable.

Most burrow systems showed oscillating patterns of activity (ranging from 1 to 146 days) and inactivity (ranging from 1 to 40 days). The average number of simultaneously active burrow systems per Morro Bay kangaroo rat in a field enclosure was 6 burrow systems per individual in the summer and 10 burrow systems per individual in the fall (Gambs and Nelson 1989).

F. Vegetation Development Within the Historic Range

Vegetation in the historic range of the Morro Bay kangaroo rat developed in response to interactions of geological events (see above) and environmental factors such as soils, parent material, climate (wind, temperature, rainfall, fog, etc.), coastal tides, drainage routes, biotic components, fire, and past and present human activities. Consequently, the remaining vegetation of this area is a complex mosaic of relatively natural terrestrial, semiaquatic, and aquatic

(freshwater and saltwater) plant communities. The natural terrestrial plant communities are pioneer coastal dune, coastal dune scrub, chaparral, coastal oak woodland, and grassland communities. Added to these natural communities are the many plants (e.g., ornamentals, windrows, crops, and weeds) introduced to the area during urban and agricultural development.

The western portion of the Los Osos Valley eastward to Los Osos Creek (the extent of the sand dune/sheet complex) is covered by a mosaic of four native plant communities: (1) pioneer coastal dune (unstabilized), (2) coastal dune scrub, (3) chaparral, and (4) coastal oak woodland. The pioneer coastal dune community occurs on the youngest and most active dunes, which are near the ocean. The coastal dune scrub and chaparral communities occur on progressively older and more stabilized dunes. The coastal dune scrub community as described by Holland and Keil (1986a) is roughly synonymous to coastal sage scrub (Munz 1968) and coastal sand plains and stabilized sand dunes (Hoover 1970). The coastal oak woodland community occupies the oldest and most stable dunes and is considered the climax vegetation in this area. Morro Bay kangaroo rats are believed to have occupied a large portion of the area currently or historically covered by the coastal dune scrub community.

G. Native Habitat Types Within the Historic Range

The west-facing Pecho area is covered by a complex mosaic of shrubby and herbaceous plants that are not arranged into well-defined communities. The pioneer coastal dune community occurs along the strand. Coastal dune scrub is located immediately east of the unstabilized dunes, and chaparral is generally restricted to older dunes east of Pecho road. Coastal dune scrub is the major plant community on the site and the principal habitat for Morro Bay kangaroo rats.

Coastal dune scrub is composed of a mixture of herbaceous, subshrubby, and shrubby plants with shallow root systems that tap water available near the surface of the soil. Dominant species are mostly soft-stemmed shrubs or subshrubs (more-or-less woody, usually low-growing plants) with thin, often deciduous or

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semideciduous leaves. Associated herbaceous species range from diminutive, spring-flowering annuals to coarse succulents, bunchgrasses, and mat-forming perennial herbs. In addition, much of the soil bears a crust-like cover of lichens that reduces soil erosion. The overall aspect of the vegetation is an open-to-dense shrubland with a predominantly gray-green color. The shrubs vary in height from about 0.2 to 2.0 meters (8 to 80 inches), but most are less than 1 meter (40 inches) tall. Species that occur in the coastal dune scrub community at Pecho are described in Gambs and Holland (1988).

The north-facing Morro Palisades area is covered by an intergrading assemblage of coastal dune scrub, chaparral, and coastal oak woodland communities. In addition, two small groves of Bishop pines and a few isolated Bishop pines occur on the upland portion of the site. In addition to the native species, eucalyptus (*Eucalyptus* spp.) and Monterey cypress (*Cupressus macrocarpa*) trees and weedy plants have invaded disturbed sites, especially along trails and near the homes bordering the northern edge of the site.

The coastal dune scrub community occupies the northern (lower) half to third of the Morro Palisades site. Like the Pecho site, the soil surface in much of the coastal dune scrub at Morro Palisades is not just bare sand, but, instead, is covered by a thin crust of lichens or a carpet of moss. These low-growing plants are an important component of mature, undisturbed dune scrub communities, stabilizing the soil surface, preventing erosion. The southern half to third of the Morro Palisades site is occupied by chaparral, which varies from an extremely dense, almost impenetrable community with virtually no understory to a relatively open community with a sparse understory in the central portion. Where the chaparral and the coastal dune scrub communities intergrade at Morro Palisades, the dominant chaparral species such as manzanita (*Arctostaphylos morroensis*) (federally listed as threatened) and buckbrush (*Ceanothus cuneatus*) are interspersed with coastal dune scrub species such as mock heather or goldenbush (*Ericameria ericoides*), California sagebrush (*Artemisia californica*), coastal buckwheat (*Eriogonum parvifolium*), deerweed (*Lotus scoparius*), and silverweed (*Horkelia cuneata*). Other plant species that occur at Morro Palisades are described in Gambs and Holland (1988).

H. Habitat Relationships

Comparisons of overall plant cover of habitat occupied by Morro Bay kangaroo rats (Morro Palisades) and habitat not occupied by Morro Bay kangaroo rats (Pecho) show substantial differences (Gambs and Holland 1988). The animals at Morro Palisades had a definitely preferred coastal dune scrub having a comparatively low plant species diversity, with high cover of buckbrush, deerweed, and silverweed and low cover of yarrow (*Achillea millefolium*), iceplant (*Carpobrotus spp.*), California aster (*Lessingia filaginifolia*), and Dudleya (*Dudleya caespitosa*). Within stands of coastal dune scrub habitat having these attributes, the sites where Morro Bay kangaroo rats were found had significantly higher silverweed cover and significantly lower croton (*Croton californicus*) cover than the stands as a whole.

In a 0.2-hectare (0.5-acre) field enclosure in which bare sand and herbaceous growth covered 68 percent of the enclosure, with the remaining 32 percent covered by subshrubs and shrubs (dominated by deerweed, mock heather, California aster, and croton), Morro Bay kangaroo rats showed no distinct locomotory preference for any of the three cover categories (Gambs and Nelson 1990). However, when constructing entrances to their burrow systems, they did show a statistically significant preference for deerweed, mock heather, California aster, and open ground.

Past and present information on preferred habitat suggests that Morro Bay kangaroo rats may select coastal dune scrub habitat in an early stage of recovery from disturbance (i.e., in an early seral stage). Such habitats are generally characterized by (1) somewhat lower plant species diversity; (2) scattered areas of bare ground; (3) increased coverage by deerweed, silverweed, and buckbrush; (4) reduced coverage by yarrow, California aster, and dudleya; and (5) moderately sparse dispersions of California sage, black sage, mock heather, and bush lupine. Sites *not* dominated by California sage, mock heather, and holly-leaved cherry appear to be more favorable to Morro Bay kangaroo rats than sites where these species dominate the habitat. Comparisons of present plant communities to communities of the past, when the Morro Bay kangaroo rat was more widespread

and populations were larger, have been prevented by the lack of quantitative plant community data in earlier studies of Morro Bay kangaroo rats. In the absence of information from the past, it should not be assumed that the compositions of plant communities inhabited by the remaining animals are optimal for them.

Brown and Harney (1993) suggested that population and community ecology of kangaroo rats and other rodent species in deserts is influenced by combinations of interacting biotic and abiotic factors, including climate, substrate, vegetation, productivity, food, competitors, and predators. There is every reason to think that Morro Bay kangaroo rat ecology is influenced by a similar set of factors.

I. Human-induced Changes in Native Habitat

Historically, Native Americans regularly set fire to the vegetation to clear it for more successful hunting (Hanes 1977, Lewis 1973). Such periodic interruption of plant succession may have been beneficial to Morro Bay kangaroo rat populations by maintaining seed-producing plants characteristic of vegetation recovering from disturbance, and preventing their replacement by shrubs characteristic of dense, old-growth stands of coastal dune scrub and chaparral communities.

In addition to residential, agricultural, and commercial development projects that have eliminated a large portion of habitat within the historic range of Morro Bay kangaroo rats, there are other instances of habitat alteration (below) that have not necessarily resulted in the permanent elimination of such areas from potential occupancy by Morro Bay kangaroo rats. There is circumstantial evidence to suggest that some types of habitat alteration may actually be beneficial to Morro Bay kangaroo rats, particularly if they occur on sites covered by old-growth coastal dune scrub or chaparral habitat.

Ordnance Removal: About 1956, heavy equipment was used to plow the Pecho area during removal of unexploded ordnance left behind from the area's use as a firing range during World War II (Stewart 1958). During this operation, virtually all plants on the Pecho site were uprooted, piled, and burned (Roest, pers. comm., 1982). By 1958, the Morro Bay kangaroo rat population at Pecho was quite high

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(Stewart 1958, Fish and Wildlife Service 1982). As plant communities have matured following the removal of ordnance at Pecho, the numbers of Morro Bay kangaroo rats there have declined.

Residential Development: The northern, more gently sloping, portion of the Morro Palisades site was cleared with heavy equipment about the same time that residential development began along Highland Drive (Roest, pers. comm., 1982). Although the exact date of this clearing has not been found, examination of aerial photographs suggests that it was completed during the mid to late 1960's or early 1970's. Aerial photos taken after 1973 show the northern portion of Morro Palisades covered with recovering coastal dune scrub. Over the past 20 years, plant communities at Morro Palisades have continued to mature following this clearing and most of the Morro Bay kangaroo rats at Morro Palisades have been found on the northern previously-disturbed area. Today, most of the habitat actually occupied by Morro Bay kangaroo rats is in parts of the cleared area that has been slowest to develop dense shrub cover and parts of the steeper uncleared area that continue to be covered with sparsely dispersed, low-growing shrubs.

Recovery Efforts: In 1982, the California Department of Fish and Game developed a management plan for the Morro Dunes Ecological Reserve that called for a rotating program of brush removal to enhance habitat quality for Morro Bay kangaroo rats on the reserve and elsewhere in the Pecho area (Lidberg 1982). In 1983, the Fish and Wildlife Service, in cooperation with the California Departments of Fish and Game, Parks and Recreation, Forestry, Corrections, and the California Conservation Corps initiated a habitat enhancement program at Pecho that involved manually removing about 30 cubic yards (less than 30 cubic meters) of iceplant throughout the area and manually thinning brush on two, 1.0-hectare (2.5-acre) experimental plots located on the Morro Dunes Ecological Reserve. Three prescribed burns were conducted on experimental plots ranging from 2.0 to 3.0 hectares (4.9 to 7.4 acres) up to 10.0 to 15.0 hectares (24.7 to 37.0 acres) between 1984 and 1986 (Gambs and Holland 1988).

Based upon a few capture records at Pecho in 1978 and 1979, it was thought that Morro Bay kangaroo rats still occupied the Morro Dunes Ecological Reserve.

After the first habitat manipulation efforts were conducted there in 1983, trapping throughout the area failed to confirm this supposition. As a result, there was no opportunity to evaluate the kangaroo rats' response to manipulation at Pecho. Gambs and Holland (1988) attempted to evaluate clearing and burning indirectly by analyzing the changes in abundance of food plants, similarity of plant cover on manipulated sites compared with sites occupied by Morro Bay kangaroo rats at Morro Palisades, and similarity of small mammal populations on manipulated sites compared with occupied sites at Morro Palisades. During the first few years after clearing, food plants were more abundant than they were in uncleared control plots. In contrast, prescribed burns reduced the abundance of food plants and increased the abundance of weedy species during the first few years after the fires. Neither clearing nor burning produced plant community types that were significantly more similar to occupied sites at Morro Palisades than were the unmanipulated sites at Pecho. Although small mammal species richness gradually dropped to three or four species on cleared sites and sharply dropped to three species on burned sites, both the number and variety of small mammals on cleared or burned sites were substantially greater than that found on occupied habitat at Morro Palisades.

J. Foraging and Social Interactions in the Field

Foraging: Foraging ecology and behavior in kangaroo rats was reviewed by Reichman and Price (1993). During the summer, Morro Bay kangaroo rats first appear on the surface immediately after dusk and then periodically throughout the night until 1 to 2 hours before dawn. Their foraging behavior typically involves "investigating" the substrate and periodically stopping for 1 to 2 minutes while the front feet are shuffled through the sand. Although Morro Bay kangaroo rats generally forage on the substrate, they also forage directly on foliage, flowers, or fruits. Occasionally they stand up on their hind legs, grab at low branches with their front feet, and vigorously shake the branches. Less frequently, they may climb and move through the overstory of branches as they forage 0.5 meter (20 inches) above the ground.

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Food items are brought to the mouth where they are either eaten or moved to the cheek pouches. Seed stored in the cheek pouches is either hoarded in the burrow or hidden in small surface-pit-caches. The conditions that result in pit-caching versus burrow-caching are unknown but would seem to include distance from the burrow to the seed patch being foraged, richness of the seed patch, and the perceived risk associated with traveling from burrow to seed patch versus pit-cache to seed patch. The individual that deposits seeds in a pit-cache should be more likely to relocate the pit-cache than other individuals foraging in the same habitat patch.

Social Interactions: Jones (1993) reviewed general social systems and social behavior of kangaroo rats. Morro Bay kangaroo rats are considered only slightly social, and their social system may be fully equivalent to their mating system. During close proximity in the field, two Morro Bay kangaroo rats may repeatedly run toward each other and then jump to opposite sides just before colliding. After several “sparring” sequences, one animal may chase the other through the brush at a high rate of speed. Each individual’s exclusive burrow system is only shared during mating encounters or while rearing pups. Individuals communicate in the field by scent marking and foot drumming. The information conveyed may include individual identification, sex, and mating condition. Foot drumming may be done on the soil surface or underground in burrows. Scent marking is accomplished by rubbing the genital region or dorsal gland (located on the back between the shoulder blades) on trails, sand bathing sites, or on the archway of burrow entrances.

K. Home Range

Stewart (1958) and Roest (1973, 1982) reported that Morro Bay kangaroo rat home ranges were quite small (0.03 to 0.07 hectare [0.07 to 0.17 acre]) and did not appear to overlap. However, these earlier estimates were made at a time when densities were much higher than they are now. For example, Stewart obtained an adjusted density estimate of 141.6 rats per hectare (57.3 rats per acre) on 1 quadrat at the Morro Palisades site in 1957.

More recent data suggest that the average home range size of Morro Bay kangaroo rats has steadily increased. Villablanca (1987) estimated that the home ranges of animals captured on traplines at the Morro Palisades site in 1986 varied from 0.19 to 0.28 hectares (0.47 to 0.69 acre). In contrast to earlier investigators, Villablanca found strong evidence that Morro Bay kangaroo rat home ranges overlapped considerably in both time and space. He found that 23 percent of all capture occasions involved simultaneous captures of two different animals at the same trap station. Furthermore, 68 percent of the 27 animals he studied were caught at stations where at least 1 other animal had been caught previously during his 3-month study.

Additional home range data were collected from 40 animals (26 females and 14 males) caught on 3 Morro Palisades plots between 1984 and 1986 (Gambs and Holland 1988). The mean home range size of 18 individuals caught 4 or more times during a single season was 0.23 hectare (0.57 acre) (95 percent confidence interval = 0.2 to 0.26 hectare). The mean home range of 11 adult females in this subset (0.233 ± 0.0199 hectare) was not significantly different from that of 7 adult males (0.232 ± 0.0224 hectare).

L. Movement and Dispersal

Previous investigators indicated that adult Morro Bay kangaroo rats remain fairly close to their main burrows and only rarely move to different localities. These observations are generally supported by Villablanca (1987) and Gambs and Holland (1988). The latter study reported that of 10 individuals followed for 2 or more years, all but 1 remained on the same plot. Apparently, once an animal establishes residency, it is far more likely to remain than to relocate. The female that changed plots was caught as a juvenile on one plot in 1984 and not seen again until 1986, 400 meters (1,300 feet) away from its initial capture location. Not only did this animal move the greatest distance between capture localities, it also had the longest documented longevity (728 days) of any animal caught during their study.

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Villablanca (pers. comm. 1987) investigated the mean distance moved between captures. The distances moved between all captures of an individual were summed and then divided by the number of captures. Twenty-nine adult Morro Bay kangaroo rats (captured a total of 151 times) had a mean distance moved between captures of 22 meters (72 feet). Eight juveniles (captured a total of 21 times) moved shorter distances; on average, only 18.5 meters (60.7 feet) between captures.

Villablanca (pers. comm., 1987) also investigated the maximum distance moved by individuals. This distance was calculated as the greatest distance between any two capture sites. Distances were pooled across trapping sessions and across years. Ninety-one percent of the maximum distances moved by 29 individuals (captured a total of 151 times) were 50 meters (164 feet) or less. Males moved distances greater than 100 meters significantly more than expected by chance (chi square for equal movement in both sexes $P < 0.005$), while females moved distances greater than 100 meters (328 feet) significantly less than expected. Likewise, males moved distances of 25 meters (82 feet) significantly more than expected, whereas females moved distances of 25 meters (82 feet) less than expected (chi square test for equal movement in both sexes $P < 0.005$). No differences between the sexes were found for maximum distances between captures of 0, 37, 50, 57, and 75 meters (0, 121, 164, 187, and 246 feet, respectively).

Dispersal distances are crudely known for Morro Bay kangaroo rats. Only three individuals have been monitored over what could be considered a dispersal phase. These movements are considered to involve dispersal because the individuals were captured more than one time at each of two different localities, or the movement occurred over a distance that exceeds the expected home range size. The dispersal distances for these individuals are 160, 250, and 436 meters (525, 820, and 1,430 feet, respectively).

Villablanca (pers. comm. 1987) found that for individuals over 200 days old there is a significant correlation ($P < 0.0005$) between age and maximum distance (or

dispersal distance) moved ($\text{distance [meters]} = -141.20 + 0.75212 [\text{age}]$), with age explaining 80 percent of the variation in distance.

Gambs and Holland (1988) attempted to predict the average distance that animals would be expected to range away from their burrows by assuming that they have circular home ranges whose area is the mean home range size (estimated by them at 0.23 hectare or 0.57 acre). They predicted that an average excursion away from the main burrow would require a Morro Bay kangaroo rat to cover a round-trip distance of at least 54.4 meters (177 feet)¹. The only field data available to evaluate their prediction were the average distances between successive captures obtained from the same 18 animals used to estimate home range size. The mean (\pm standard error) of average distances between captures for these 18 animals was 23.9 ± 4.0 meters (79.4 ± 13.1 feet), which was surprisingly close to the hypothesized radius of 27.2 meters (89.2 feet).

M. Genetics

Information on the degree of genetic differentiation within the Morro Bay kangaroo rat subspecies and between the Morro Bay kangaroo rat and closely related kangaroo rats is needed to identify genetic subpopulations, relative levels of inbreeding, changes in inbreeding over time, suitability of the Lompoc kangaroo rat (*Dipodomys heermanni arenae*) as a behavioral and ecological surrogate, and to assess the genetic distinctness of the Morro Bay kangaroo rat. Preliminary data show no observable variation within or between two samples, separated by 68 years (1918, n=8 and 1986, n=8), of Morro Bay kangaroo rat mitochondrial DNA, cytochrome b gene (Matocq et al. 1995). However, a sample of 15 Lompoc kangaroo rat specimens produced 5 distinct genetic groups, known as haplotypes.

¹ 54.4 meters = $2 \times \sqrt{(2326/\pi)}$; radius (meters) equals the square root of area (square meters) divided by pi.

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There are at least three possible interpretations of these results: (1) Morro Bay kangaroo rats may have “squeezed” through at least one population bottleneck before 1918, (2) the Morro Bay kangaroo rat subspecies had a small founder population, and (3) Morro Bay kangaroo rats have had a recent origin. These results imply that inbreeding depression in Morro Bay kangaroo rats may not be as severe as previously thought because they apparently experienced restricted population conditions in the past.

N. Diet

Seeds are a primary and nutritionally important part of the diet of *D. heermanni* (Kelt 1988); however fruits, buds, leaves, stems, insects, and land snails appear to be seasonally important (Stewart 1958, Fish and Wildlife Service 1982, Nowak 1991). No experimental studies on the food preference of Morro Bay kangaroo rats have been conducted. Stewart (1958), however, presented captive animals with seeds from a variety of locally occurring plants and recorded which species were accepted.

Roberts and Rall (1991) found that captive animals maintained on a mixed food source containing lettuce, rolled oats, red millet, sunflower seed, mouse chow, golden millet, and canary seed selected a diet that lacked an appropriate ratio of calcium to phosphorus and was deficient in calcium and manganese. Increasing the intake of mouse chow (with free water provided as an adjunct) was an effective method of correcting these deficiencies. Proper dietary intake, access to food caches, housing temperatures near thermoneutrality, and social contact all contribute to improved body condition and reproductive activity in captive Morro Bay kangaroo rats (Roberts and Rall 1991 and 1993).

O. Reproduction in the Wild

Roest's (1984) summary of museum and live trapping data collected through 1979 reports that of 24 females with embryos, 83 percent were caught in May, 13 percent were caught in June, and 4 percent were caught in August. Of the 115 immature specimens he examined, 56 percent were caught in August, 17 percent

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were caught in May, 12 percent were caught in July, and the remaining 15 percent were caught in March, April, June, September, or November. The seven immature animals reportedly caught in November were specimens taken by Dixon (1918) and housed at the University of California, Berkeley, Museum of Vertebrate Zoology (MVZ). All of the specimens collected by Dixon as well as Dixon's field notes were examined by Gambs, who determined that 10 immature Morro Bay kangaroo rats were caught in 1918, between September 25 and 27. Thus, the latest recorded date of capture for an immature Morro Bay kangaroo rat was September and the earliest recorded date was March.

Field trapping data gathered from 1984 through 86 included four conspicuously pregnant females; one was caught in April, two in June, and one in July (Gambs and Holland 1988). Of nine females that showed conspicuous signs of lactation, three were caught in April, two in May, two in June, one in July, and one in August. These limited data suggest that pregnancy, parturition, and lactation occur most frequently between March and August.

To clarify and elucidate whether or not there was a recognizable peak in breeding behavior among the Morro Bay kangaroo rats at the Morro Palisades site, Gambs and Holland (1988) and Gambs et al. (1988) first developed a regression equation for age versus body weight derived from known-aged Morro Bay and Lompoc kangaroo rats raised in the laboratory. The predicted age of immature animals was determined by rearranging the regression equation [$Y = -36.7299 + 50.5566 (\log_{10} \text{ age})$] to the form below:

$$\text{PREDICTED AGE (days)} = 10^{[\text{body weight (grams)} + 36.7299] / 50.5566}$$

By applying this equation to the weights of 21 immature Morro Bay kangaroo rats caught at Morro Palisades from 1984 through 1986, their age at the time of capture could be estimated. Assuming no delays in the reproductive cycle, it was then possible to predict the date that these 21 animals were conceived using the following backdating procedure:

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PREDICTED CONCEPTION DATE = Date of Capture - Predicted Age - 31 Days

The range of predicted conception dates for these 21 animals was from January to July. Nearly half (48 percent) of all conceptions were predicted to occur in April, and about three-quarters (76 percent) were predicted to occur between March and May. Although these results indicate that the majority of breeding in the wild occurs in early to mid-spring, they do not imply that Morro Bay kangaroo rats never breed in the summer. Of the 10 immature animals caught by Dixon (1918), the distribution of estimated conceptions dates were 2 in June, 6 in July, and 2 in August. Females involved in summer breeding may be older adults producing their second litters or yearling females that reach reproductive maturity later in the year.

The fact that captive females exhibit estrus throughout the year and may produce litters in late fall and early winter (Roest 1988) suggests that the narrower, seasonal pattern of breeding seen in wild populations is probably a consequence of fluctuations in exogenous factors such as moisture, temperature, or food supply.

P. Reasons for Listing and Current Threats

Several factors contributed to the decline and the need to list the Morro Bay kangaroo rat, as discussed previously. Many of these factors still exist within the range of the Morro Bay kangaroo rat and include direct loss of habitat from urban development, changes in the vegetation characteristics of the remaining habitat, predation by domestic and feral cats and dogs, destruction of burrows by vehicles and pedestrian traffic, competition with other burrowing rodents, fragmentation of larger populations into small subpopulations, and perhaps inbreeding (Roest 1982, Gambs 1986b, Gambs and Holland 1988, and Gambs and Nelson 1989, Gambs 1990).

Q. Conservation Measures

Reproduction in Captivity: The first formal captive breeding program for Morro Bay kangaroo rats was conducted at California Polytechnic State University (Cal Poly), San Luis Obispo, California from 1984 to 1988 (Roest 1991). A total of 10 wild animals were brought into captivity (4 in 1984, 5 in 1985, and 1 in 1986). During this period, 7 captive bred litters were produced from matings of 4 out of 18 females and 3 out of 15 males. Four additional litters were produced by females that were bred in the wild. Of the 31 young in these 11 litters, 8 were stillborn and 23 survived (12 males and 11 females). The average number of live pups per female per year was 1.44. The mean annual growth rate of the Cal Poly colony was 18 percent, whereas the mean annual mortality rate was 13 percent over the 4 year study (Roberts and Rall 1993).

Continued funding was not available for the Cal Poly program, so in 1989, the 21 remaining Morro Bay kangaroo rats (9 males and 12 females) from Cal Poly were transferred to the Piedras Blancas Field Station² (Rathbun et al. 1989). During the year or so that the colony was at Piedras Blancas, 4 copulations were obtained from 40 pairings involving 7 females, but no pups were born (Rathbun et al. 1990). Old age, male impotency, high levels of male/female aggression or incompatibility during pairing, and small colony size appeared to contribute to diminished cycling and lack of reproduction. Disease, old age, and unknown factors were responsible for the deaths of 14 of the Morro Bay kangaroo rats at Piedras Blancas.

Insufficient funds and personnel precipitated development of an interagency agreement to transfer the colony (four males and three females) from the Piedras Blancas Research Station to the Department of Zoological Research (DZR) at the National Zoological Park (Roberts and Rall 1993). Acquisition of permits and the negotiation of agreements and contracts delayed the physical transfer of animals

² Piedras Blancas Field Station was operated at the time by the Fish and Wildlife Service. It has since been transferred, along with other research activities, to the Biological Resources Division of the U.S. Geological Survey.

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for a full year (fall 1989 to fall 1990). During this hiatus, research was suspended and the colony was placed in a maintenance mode.

A broad-based research program was initiated soon after the National Zoological Park received the captive colony in November 1990. Dietary preference and food analysis studies at the Department of Zoological Research showed that Morro Bay kangaroo rats and Lompoc kangaroo rats selected a diet deficient in calcium and manganese with an inappropriate calcium:phosphorus ratio (Roberts and Rall 1991). In addition to nutrition studies, housing, environmental, and husbandry conditions were systematically evaluated and adjusted to optimize metabolic efficiency. Results of these initial studies were used to improve body condition and survivorship of animals in the colony. Subsequent studies showed that maintaining temperatures within thermal neutrality and providing housing conditions that permitted olfactory, auditory, visual, and tactile social contact further contributed to increased body mass and higher condition indices, especially among females (Roberts and Rall 1993). High condition indices were found to be strongly associated with more frequent and more predictable estrous cycles. Despite the advanced age of Morro Bay kangaroo rats in the colony, females continued to cycle during their first year at the Department of Zoological Research. However, by the second year of the study, only the younger Lompoc kangaroo rats were cycling; apparently the Morro Bay kangaroo rats had become reproductively senescent (Roberts and Rall 1993). Social behavior studies with Lompoc kangaroo rats showed that the level of aggressive behavior during experimental pairings could be substantially decreased by allowing pairs to gain social familiarity prior to pairing (Thompson 1993). In addition to diminishing aggressive behavior, social familiarity also facilitates weight gain and thus improves condition indices in female Lompoc kangaroo rats (Thompson 1993).

At the present time, the state of knowledge concerning reproductive physiology and reproductive behavior of both the Morro Bay kangaroo rat and the surrogate Lompoc kangaroo rat is insufficient to permit successful application of technologically-advanced reproductive biotechniques (e.g., collection and cryopreservation of germ plasm, artificial insemination, or embryo transfers) on these animals (Roberts and Rall 1993).

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Roberts and Rall (1993) encountered a number of handicaps associated with having the captive colony too far removed from the wild populations under investigation. They recommended that future captive breeding research be relocated to a site much closer to the wild populations. Such a move would provide easier access to wild stock, better communication with State and Federal agencies charged with Morro Bay kangaroo rat recovery, and greater opportunity to observe and experiment with wild populations or their habitat.

In 1992, Dr. Sonja Yoerg submitted proposals to the Fish and Wildlife Service and the California Department of Fish and Game to transfer the captive breeding research program from the National Zoo to facilities provided by the Department of Psychology, University of California, Berkeley. Funding for the first year of this research was approved by the California Department of Fish and Game in early 1993. This program experienced the highest reproductive success thus far in captive breeding of the closely-related subspecies, the Lompoc kangaroo rat.

In 1996, the California Department of Fish and Game amended a contract with the University of California, Berkeley, to continue a captive-breeding program designed to ultimately benefit the Morro Bay kangaroo rat. The principal investigator is Dr. William Z. Lidicker, Jr., Museum of Vertebrate Zoology and the project director and primary researcher is Dr. Sonja I. Yoerg, Museum of Vertebrate Zoology and Department of Psychology. Because there are no Morro Bay individuals remaining in captivity, all the work is done with Lompoc kangaroo rats as surrogates. Procedures for the project are:

1. Maintain appropriate housing for kangaroo rats at the University.
2. Perform pairings of kangaroo rats to determine how to initiate the estrous cycling of females and to determine how to successfully pair captive animals.
3. Conduct studies to determine aspects of antipredator and social behavior.
4. Release kangaroo rats to the wild if appropriate conditions have been met.

The project has demonstrated that kangaroo rats, both wild-caught and captive born, will breed and produce young in captivity (Gustafson 1997).

Introduction of Captive Surrogate Animals into the Wild: As a prelude to future introductions of Morro Bay kangaroo rats, four Lompoc kangaroo rats were released in May and July 1986, at “Dune Lakes Limited,” about 8 kilometers (5 miles) southwest of Arroyo Grande, California, on the Nipomo Mesa (Gambs 1986f). Two animals were released into a portable enclosure and monitored for several weeks at each of two locations. The enclosure surrounded about 650 square meters (7,000 square feet) of habitat that was occupied by resident Lompoc kangaroo rats, deer mice, and western harvest mice. Two 14-month-old full sibling males that had been born in captivity were used on the first introduction trial. Each animal was initially introduced into an artificial burrow constructed with a 5-centimeter (2-inch) soil auger. Both animals readily excavated additional tunnels, which undoubtedly intersected tunnel systems of resident animals. One of the two males was found dead outside the enclosure 2 weeks after its introduction. The probable cause of death was internal injury inflicted by puncture wounds from either another kangaroo rat or a small (e.g., weasel-sized) mammalian predator. The other male was recaptured 2 weeks after its introduction and appeared to be in good physical condition. On the second introduction trial, one 3½-year-old wild-caught male that had been in the breeding colony and one 3-month-old captive-born male were released at a different site. They also readily excavated new burrows, but by the end of the first week, the older male’s body weight had dropped 20 grams (0.7 ounce), and he was found dead 12 days after his release. The younger male initially lost weight, but after 13 days in the enclosure, weighed 4 grams (0.14 ounce) more than when released. Despite abundant supplemental food in the enclosures, no more than 50 percent of the Lompoc kangaroo rats survived longer than 2 weeks. The youngest captive-born animal released showed better weight gain under field conditions than older animals, whereas the oldest and only wild-caught animal released during the study experienced severe weight loss.

Captive Morro Bay kangaroo rats were introduced into a permanent 2.0-hectare (5-acre) enclosure located on federally-designated critical habitat at Pecho that had been experimentally burned 4 years earlier (Gambs and Nelson 1989, 1990). California ground squirrels and snakes were removed from the enclosure prior to the release of Morro Bay kangaroo rats. No attempt was made to exclude deer

mice, California pocket mice, or western harvest mice which moved freely through the 1.3 centimeters (0.5 inch) aviary wire fence. During May 1988, a 2-year-old captive-born male, a 4-year-old captive-born female, and an over-3-year-old wild-caught female that had been in captivity were introduced into the enclosure. A second 2-year-old captive-born male was introduced in July, when it appeared that the first male had disappeared. The 2 females and the second male excavated and maintained an average of 6 burrow systems per individual during the summer and 10 burrow systems per individual during the fall. These animals were in very good physical condition through the summer and fall, but showed no signs of breeding. The male burrowed below the buried fencing (82 centimeters [32.3 inches]) and escaped from the enclosure in November. Despite intensive trapping the following year, no signs of these or other Morro Bay kangaroo rats were found in the Pecho area during the 1989 field season.

The low persistence rates and lack of reproduction observed when captive-born and captive-maintained Lompoc and Morro Bay kangaroo rats were experimentally released to the wild differs sharply from the results of translocation experiments with other kangaroo rat species. Williams et al. (1992) observed a 50 percent persistence rate over 1 year and vigorous reproduction when they translocated colonies of 30 giant kangaroo rats (*D. ingens*) to formerly-occupied habitat. Likewise, Michael O'Farrell (pers. comm., 1992) observed a 30 percent persistence rate over 8 to 12 months and vigorous reproduction in translocated colonies of up to 40 Stephens' kangaroo rats (*D. stephensi*). The Stephens' kangaroo rats were held in captivity temporarily before being translocated to formerly-occupied habitat. Translocated populations of Stephens' kangaroo rats that had higher growth rates also showed higher turnover rates and vice versa.

R. Recovery Strategy to Prevent Extinction

1) Increase the population size of Morro Bay kangaroo rats. Increased population size is essential to reducing both the short and long-term chance of extinction. Now that captive breeding experiments with *D. h. arenae* appear

successful, the next strategy should be to capture a substantial number, quite possibly all, of the remaining wild Morro Bay kangaroo rats and breed them in captivity. The justification for such a drastic measure is the immediate, short-term threat of extinction, which is closely and inversely correlated with population size. Small populations are extremely vulnerable to a variety of chance events that affect larger populations less severely. Rapid expansion of the population through captive breeding also slows the loss of genetic variability in the population. Populations lacking genetic variability are vulnerable to extinction because the “adaptive” or “evolutionary” potential of a population is a function of its ability to present genetic variation to natural selection. Populations with substantial genetic variation are expected to persist longer under variable or extreme selective pressures better than those with low genetic variation. In addition, a genetically homogeneous population is expected, in most cases, to have reduced immunological resistance, which increases the chance of extinction by common infectious agents.

2) Aggressively pursue habitat acquisition, and habitat access and management programs. The future population size of wild Morro Bay kangaroo rats depends directly on how much habitat is available. Estimates of habitat requirements indicate that a self-sustaining population will require more habitat than is currently occupied. Assuming a mean density of 10 animals per hectare (4 per acre), approximately 200 hectares (500 acres) of productive habitat will be required to improve the species’ status. If habitat is not managed to sustain a mean density of 10 animal per hectare (4 per acre), more land will be required. Priority should be given to acquisition of the largest habitat patches that are closest to other large patches, to facilitate dispersal by kangaroo rats. Dispersal into a patch is expected to increase as the patch size increases and distance from other large patches decreases. The management of plant community succession will help maintain the largest possible populations of Morro Bay kangaroo rats on existing habitat. The Morro Palisades parcel may be the most important parcel to acquire.

Acquisition of Morro Bay kangaroo rats for captive propagation and reintroduction research will require access to private lands. Although several

moderate-sized parcels exist, many small private parcels containing potential habitat for Morro Bay kangaroo rats are scattered throughout the Los Osos/Baywood Park area. Human-caused disturbances continue to degrade remaining habitat patches that may still support the few remaining populations of Morro Bay kangaroo rats.

3) **Increase research efforts aimed at understanding the basic biology, life history, habitat use, and genetics of Morro Bay kangaroo rats.** Management decisions aimed at enhancing Morro Bay kangaroo rats must be based on sound biological and ecological knowledge of the species. With improved knowledge of the species, we are more likely to choose the correct management and conservation strategies.

4) If the number of Morro Bay kangaroo rats is too few to establish a captive breeding population, a possible status-improvement strategy to deal with this extreme circumstance would be to **cross the very few remaining Morro Bay kangaroo rats with their nearest genetic relatives.** Although the implications of this would require careful consideration, this strategy should at least be mentioned here because we do not know the present status of Morro Bay kangaroo rats.

II. RECOVERY

Objective and Criteria

Based purely on genetic considerations, Morro Bay kangaroo rats may be reclassified as threatened when an effective genetic population size (N_e) of 500 has been achieved (translating to an actual census size of about 2,000 individuals), and then sustained with a mean at that level for 10 consecutive years, with adequate geographic distribution. These 2,000 animals should represent the greatest proportion of genetic variability that can be captured from the extant population. Genetic variation decreases in response to small effective population sizes and it decreases in response to the number of generations a bottleneck lasts. It is therefore imperative that population growth is maximized during all stages of the recovery program.

This effective population size can be achieved with a combination of captive, semicaptive, and wild animals, as long as variability of genetic information in the entire population is maximized and all three portions of the population are maintaining genetic interchange. However, any change in the status of the Morro Bay kangaroo rat should be based on the effective population size (N_e) of the subspecies in the wild. Overall status may be augmented by a captive portion of the population, but is not equivalent to it. Captive populations are only biologically and ecologically viable if they are directly or genetically contributing to a current or future wild population. The goal is to develop a sustainable wild population, not maintain a taxon in a biological and ecological vacuum.

Narrative and Outline for Recovery Tasks

All seven categories of recovery tasks are so interdependent that, because of the critical status of the Morro Bay kangaroo rat, they are all considered priority number 1 tasks.

1 Continue to develop and refine captive propagation techniques for the surrogate species, the Lompoc kangaroo rat (*Dipodomys heermanni arenae*), and the Morro Bay kangaroo rat.

Recovery of the Morro Bay kangaroo rat requires an immediate, rapid increase in population size to retain genetic variation and protect remaining populations from continuing decline or the chance of mass mortality. Because wild populations of Morro Bay kangaroo rats are critically small and fragmented, and suitable habitat is extremely limited and degraded continuously, expansion of wild populations in the near future is extremely unlikely. Therefore, self-sustaining captive populations of Morro Bay kangaroo rats must be established to 1) rapidly increase total Morro Bay kangaroo rat population size, 2) secure a genetic pool isolated from the potential natural and human induced disasters in the wild, and 3) provide a long-term population and genetic resource for supplementing existing wild populations or establishing new wild populations in the future. The interdependent actions described here and in other sections of this outline ultimately converge at a point where successfully reintroduced or translocated Morro Bay kangaroo rats develop into vigorous, self-sustaining populations in the wild.

11 Continue to breed the surrogate species (Lompoc kangaroo rat) in captivity to establish captive breeding and management parameters.

Much has been learned about the husbandry requirements of *Dipodomys heermanni* in captivity, especially through programs like the captive-breeding project at the University of California, Berkeley. Because reproduction may occur in only a small fraction of the wild animals brought into captivity, establishment of a self-sustaining captive colony will require the initial acquisition of a large number of animals from the wild. Morro Bay kangaroo rat numbers in the wild are unknown but recent estimates of the distribution and quality of suitable habitat suggest that wild populations may already be too small and fragmented to sustain viable numbers in the wild after a “take” to establish a captive colony. Therefore, techniques for captive management

and reproduction are being developed on a closely-related surrogate species to maximize the probability of success with Morro Bay kangaroo rats.

111 Continue to maintain an open population of at least 50 Lompoc kangaroo rats at the present captive breeding facility at the University of California, Berkeley.

The Lompoc kangaroo rat (*Dipodomys heermanni arenae*) is believed to be the most closely related subspecies to the Morro Bay kangaroo rat, both genetically and ecologically. In fact, introgression³ may have occurred between these two subspecies at various times in the distant past. Therefore, the Lompoc kangaroo rat is considered the most suitable surrogate subspecies. While genetic management of the surrogate is not strictly required, techniques should be developed for maximizing founder reproduction as this will be necessary when work on Morro Bay kangaroo rats begins.

Captive colonies of the Morro Bay kangaroo rat and its surrogate, the Lompoc kangaroo rat, should be maintained in California. Situating captive colonies near the natural range of the Morro Bay kangaroo rat greatly simplifies acquisition of animals from the wild and, later, the exchange of animals between captivity and the wild when reintroduction/translocation efforts begin. It also helps foster the necessary interaction between Morro Bay kangaroo rat conservation and research efforts in the wild and in captivity, including the application of information obtained on wild populations to managing captive animals (e.g., behavioral and nutritional requirements). Finally, a California location should also enhance interaction with local community groups, businesses, institutions of higher learning,

³ Introgression is the movement of genes from one species to another, usually via hybridization. Subspecies are by definition not so genetically isolated from each other as full species.

and zoos that could potentially provide critically needed resources and assistance for the conservation program.

- 112 Conduct focused research on reproductive behavior and physiology at a suitable facility (as indicated in task 111) that will ensure the goal of doubling the captive population every 2 years and to determine critical factors necessary for captive breeding of the Morro Bay kangaroo rat, and possibly other endangered kangaroo rats.**

Considerable time, money, and other resources have been devoted to captive breeding of Morro Bay kangaroo rats during the last decade with mixed results. While a firm foundation of captive husbandry has been established, consistent progress in captive reproduction is still needed. Focused research on reproduction in the surrogate should be continued with the specific objective of doubling the captive population every 2 years. This work must be transferred to Morro Bay kangaroo rats as soon as suitable progress with the surrogate can be demonstrated. A preliminary criterion for suitable progress would be a doubling of the population every 2 years. The generation time for these animals is considered to be 1 year because of seasonal variation in reproductive condition in both laboratory and field populations. Adequate and predictable funding for captive propagation is essential to ensure full-time animal care and research activities for an initial colony of about 100 animals that is expected to double every 2 years.

- 113 Develop intensive husbandry and breeding techniques that will increase captive carrying capacity to a point where several institutions are participating in the captive breeding program.**

A rapid and dramatic increase in the number of Morro Bay kangaroo rats is required to produce the captive population and genetic pool necessary to ensure a long-term, self-sustaining captive population. It

is unlikely, and even inadvisable that any single institution will be able to accommodate this large number of animals. Therefore, it is recommended that other California institutions be recruited as adjunct breeding/exhibition facilities to increase captive carrying capacity. All recruited institutions should be managed under a single management scheme along the lines of the Species Survival Programs (SSP) of the American Association of Zoological Parks and Aquariums (AAZPA). Accordingly, it will be necessary to develop standardized husbandry and breeding protocols as soon as possible.

12 Develop, implement, and evaluate laboratory techniques to prepare captive animals for reintroduction or translocation using the Lompoc kangaroo rat.

Results from experimental reintroductions and translocations of Lompoc kangaroo rats will be used to develop techniques to increase the chance that captive-born Morro Bay kangaroo rats will become successfully established in managed habitats. Adopt an experimental approach that is integrated with the captive-breeding program (refer to task 11). Determine the type, length, and intensity of training necessary to maximize short and long-term success of animals introduced to the wild. Evaluate social learning effects (adult-juvenile, sibling-sibling) that are important to successful establishment in the wild.

121 Develop and implement techniques for antipredator training.

Use conditioning techniques on captive animals to establish appropriate antipredator responses in animals prior to their release into the wild. Evaluate cross-modal and cross-predator transfer of learned behaviors.

122 Develop and implement techniques for foraging training.

Evaluate diet selection and foraging strategies (e.g., harvest rates, microhabitat choice, foraging-predation interactions) in captive animals. Test food preferences in captive animals and incorporate this information into habitat improvement programs. Information from these experiments also should be incorporated into food supplementation programs that may be undertaken on wild populations.

123 Develop and implement techniques for social training.

Investigate social and competitive interactions in young captive animals and the influence of social interactions on timing of sexual maturity and competence. Determine the role of siblings and parents in modifying early social interactions.

124 Ascertain the development of survival skills to optimize timing of release.

Compare the speed of acquisition and maintenance of relevant behaviors at different developmental stages. Investigate the way in which the development of various skills (e.g., social, foraging, anti-predator) interact.

13 Begin a captive propagation program for the Morro Bay kangaroo rat that will provide a secure source population for reintroductions. Make provisions to obtain sufficient Morro Bay kangaroo rats from wild populations to ensure that at least 20 (preferably 100) contributing founders are obtained.

The ultimate objective of the captive breeding program is to propagate Morro Bay kangaroo rats in sufficient numbers to provide secure, genetically diverse adjunct captive populations to buffer against catastrophic extinction of the

wild Morro Bay kangaroo rat populations, and to provide animals for reintroduction. From a genetic standpoint, all animals that can be captured in the wild should be placed in an intensively-managed captive breeding program. Time is paramount because all genotypes that cannot be incorporated into a rapidly growing captive population will be effectively extinct. Captive breeding of Morro Bay kangaroo rats should proceed as outlined for the Lompoc kangaroo rat (refer to task 11) as soon as sufficient progress has been demonstrated for the surrogate.

131 Remove Morro Bay kangaroo rats from the wild.

Although it is likely that Morro Bay kangaroo rats exist only at the Morro Palisades site, this task strategy is designed to accommodate the possibility that other populations can be found.

Translocation of wild animals from one site to another is not recommended at this time.

Each individual taken into captivity will be identified as to sex and age, weighed, and assessed for reproductive condition, physical injuries, diseases, and ectoparasites before being moved into captivity.

If Morro Bay kangaroo rats are captured from some habitat patches under emergency conditions before all captive breeding techniques are known, it is recommended that they be managed like the surrogate until decisions are made on whether to take additional Morro Bay kangaroo rats and the nature of their disposition. Once a commitment has been made to fully support a Morro Bay kangaroo rat propagation program, action should proceed as outlined for the surrogate in tasks 111, 112, and 113.

132 Conduct Genetic Analyses.

Recovery criteria and specific recommendations will be sound if they are based on a real understanding of Morro Bay kangaroo rat population genetics and population dynamics. Uncertainty within these two areas is currently high. Knowledge of genetic variability and population dynamics of Morro Bay kangaroo rats is crucial to implementing actions necessary to prevent extinction and ultimately reclassify the Morro Bay kangaroo rat.

The genetic analyses described below will verify the preliminary information described in Part I and greatly expand our understanding of Morro Bay kangaroo rat population genetics. The goal of this section is to outline what information is necessary, how to collect it, and how to integrate it into the decision-making process. Specific circumstances as well as the state of technology will dictate which of the genetic analysis methods described below are necessary and feasible.

1321 Conduct tissue sampling.

Tissue samples should be obtained from all Morro Bay kangaroo rats captured in the field (whether released at the site of capture or taken into the captive breeding colony). Necessary permits and approval of training for personnel should be provided by the Fish and Wildlife Service and the California Department of Fish and Game. A pie-shaped wedge of tissue (chord of 1.5 millimeters and a radius of 2 millimeters) cut from the margin of the ear should be collected using standard DNA voucher collection methods. Blood from the infraorbital sinus should be collected if an electrophoretic survey of blood proteins (protein electrophoresis) is the only genetic survey to be attempted and if handling and bleeding is done by a highly experienced collector. These tissues should be stored in the

Museum of Vertebrate Zoology (UC Berkeley), a frozen tissue collection approved by the American Society of Mammalogists, granted that the curators are given full and perpetual permission to administer those tissues.

1322 Conduct mitochondrial DNA analysis.

This is the most variable portion of the genome that can be reliably compared between populations. Population-size samples of the Morro Bay kangaroo rat and the Lompoc kangaroo rat should be surveyed for allelic⁴ variation. The specific loci to be surveyed will be determined after consulting studies on other kangaroo rat species. This data base should be used to estimate (1) the level of genetic polymorphism in the Morro Bay kangaroo rat relative to other kangaroo rat populations, (2) the relative genetic effective population size (N_e) as compared to other kangaroo rats, and (3) the level of gene flow between the Lompoc and Morro Bay kangaroo rat. The data base will also allow assessment of systematic relationships and genetic differentiation of the Morro Bay kangaroo rat by comparison to published data sets on other kangaroo rats.

1323 Survey historical mitochondrial DNA variation.

Using the same loci described in task 1322 and the more than three dozen museum study skins located at the Museum of Vertebrate Zoology, UC Berkeley from 1918, prebottleneck genetic variability should be evaluated. This information, in

⁴ Different versions of genes are called alleles. Mitochondria, which are organelles within cells, have comparatively short strands their own DNA, with genes, separate from the cell's nucleus. While nuclear DNA in mammals is inherited from both parents, mitochondria and their DNA are inherited only from the mother.

conjunction with the data from task 1322, can be used to estimate (1) the absolute reduction in genetic variation resulting from the current population reduction, (2) the relative change in the level of inbreeding, and (3) the likelihood that the Morro Bay kangaroo rat has survived previous bottlenecks.

1324 Survey nuclear DNA variation.

Using the same skin samples collected in task 1321, nuclear DNA should be tested for genetic variation. It is possible that nuclear DNA sequences will show sufficient variation to provide all the estimates sought in task 1322. Most likely, nuclear DNA will only provide estimates of heterozygosity and possibly estimates of genetic differentiation relative to other closely related populations. This information could be valuable for micromanagement of captive breeding. In addition, screening nuclear loci (e.g., using single-strand conformational polymorphism, denaturing gradient gel electrophoresis, or related methods) would be less costly and more time-efficient than sequencing them. If significant variation is found, DNA sequences should be obtained in order to evaluate the robustness of parameters estimated in task 1322. Since nuclear DNA is biparentally inherited, in contrast to strict maternal inheritance of mitochondrial DNA, a survey of nuclear DNA would (1) validate the results obtained from surveying a single locus (mitochondrial DNA) and (2) it would flesh out any differences in genetic structuring due to life history variation between males and females. Specifically, a survey of nuclear DNA could suggest differences in dispersal strategies and it would permit comparisons of the variance in reproductive success between the sexes. If the survey of nuclear DNA were extended to include samples from museum specimens, then more robust conclusions could be reached regarding historical inbreeding levels as well

as the absolute amount of loss in variability due to the current population bottleneck.

1325 Conduct microsatellite DNA analysis.

This analysis would provide a measure of population heterozygosity, and may be required to obtain all desired information for genetic assessments, but techniques will need to be worked out for kangaroo rats. This approach gives fine scale spatial and temporal information regarding population structure, gene flow, and inbreeding. It is probably a better complement to mitochondrial DNA assessments than nuclear DNA sequencing would be. However, the technical application of microsatellite DNA analysis is still in the developmental stages, particularly for kangaroo rats. Since the technical constraints are temporary, microsatellite DNA analysis should be given serious consideration once it becomes routinely applicable. Ear tissue would be appropriate for this form of genetic evaluation.

1326 Survey genetic variation in blood proteins.

Using blood samples, evaluate genetic variation in blood proteins using standard protein electrophoretic techniques. This survey provides the least expensive and least sensitive survey of genetic variation. Potentially, estimates could be obtained for some of the parameters estimated in task 1322. As in nuclear DNA, it is unlikely that this survey would provide a sufficiently fine level of resolution, unless Morro Bay kangaroo rats are highly differentiated from other kangaroo rats. If personnel expert at collecting kangaroo rat blood are not available, the potential for mortality during sample collection argues against conducting this task. Due to the potential danger and potentially low value of the data, unless Morro Bay kangaroo rats are found

to be highly differentiated from other kangaroo rats, this task has the lowest priority among the genetic analysis procedures.

133 Conduct a pilot captive breeding program for the Morro Bay kangaroo rat, with initial emphasis on research on reproductive physiology and behavior.

This task follows those outlined for the surrogate in tasks 111 and 112. Fund and maintain captive populations large enough to preserve at least 90 percent of genetic variation of the founder population for at least 10 years. A relatively large number of founders for the captive breeding program, preferably 100, is recommended to minimize the loss of genetic variation and achieve sufficient numbers of animals to support a short-term (at least 10 years), growing captive population of at least 500 animals that will be able to supply animals for reintroduction efforts. A cooperative funding effort between Federal, State, and other agencies and institutions should be initiated.

The program should maintain the expanding captive colony intact at a single site for long enough to establish the efficacy of captive breeding under the best available conditions. It is therefore essential to seek supplemental or alternative sources of funding to ensure the program's continuity. An initial commitment by the Fish and Wildlife Service of about \$30,000 per year for 3 years, to be matched in kind or by grants from the collaborating institution(s), is recommended. Additional sources of private and Federal funding should be cultivated to raise the total sustained funding level to at least \$100,000 per year (refer to task 7).

- 134 Once adequate methodologies for captive breeding have been developed, transfer additional Morro Bay kangaroo rats from the wild and establish at least two separate populations to achieve the goal of doubling the population every 2 years.**

Acquisition of additional animals will require access to lands that support the only known wild population (refer to tasks 2 and 3). A long-term, self-sustained captive colony should be housed in at least two, preferably more, California sites to ensure that a catastrophic event at one institution (e.g., infectious disease, fire, earthquake) will not decimate the entire captive population. As discussed above, a genetic and demographic management plan should be initiated to manage the captive population to minimize inbreeding, ensure parity of founder contributions, and effect a stable age distribution in the captive population. Application of rational genetic and demographic management techniques will readily enable identification of “surplus” animals based on their genetic makeup, mean kinship, age, fecundity, etc., so that genetically and demographically sound adjunct captive populations can be established for reproduction, exhibition, or education programs at participating institutions.

- 14 Pursue a research program on the captive population to benefit field conservation efforts.**

Certain types of information pertinent to conservation and management can be collected more rapidly and cost-effectively in the laboratory than in the field (e.g., behavioral and life history data). A successful breeding colony of Morro Bay kangaroo rats will generate precisely the sort of data needed to design an integrated management program, both in captivity and in the wild, for the recovery of the Morro Bay kangaroo rat. A program should be developed immediately to collect the data.

- 141 Gather information on life history, behavior, and reproductive biology that will provide information for developing demographic and genetic management techniques for the wild population and for future reintroduction and translocation efforts (refer to tasks 1, 2, 4, and 5).**

A comprehensive data collection framework should be devised to ensure that all relevant data are collected during the course of the captive breeding program. In addition, much useful life history and demographic information necessary for wild and captive population management modeling can be collected opportunistically by using sound, focused record-keeping practices.

- 142 Train Morro Bay kangaroo rats for reintroduction.**

Develop and implement foraging, antipredator, and social training for captive animals.

The step-down process by which captive-bred animals are selected and prepared for reintroduction is outlined under task 4.

- 15 Secure access to Morro Bay kangaroo rats and their habitat.**

Access is needed for at least 5 years, and preferably 10 or more years, to privately-owned lands in order to conduct activities described under tasks 1 and 2. The highest-priority site for access is the private Morro Palisades parcel in Los Osos, which has the only population known to be extant within the past several years. In addition, Los Osos Oaks State Preserve and a small private parcel adjacent to the Los Osos Oaks State Preserve appear to have habitat suitable for the species. Priority for obtaining access to other privately owned fragments of potential Morro Bay kangaroo rat habitat is as follows: private property adjacent to the Pecho site, the Buckskin site, and the Santa Ysabel/Junior High sites. Priority of access to publicly-owned

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fragments of potential Morro Bay kangaroo rat habitat (in addition to the Los Osos Oaks State Preserve) is, first, the Pecho North and South sites at Montana de Oro State Park, then the Hazard North and South sites (also at Montana de Oro State Park).

2 Conduct population and habitat surveys and assessments.

Detailed information is needed on the habitat relationships and requirements of Morro Bay kangaroo rats in order to design projects to enhance habitat to make it suitable for receiving introduced populations. The following measures are required: (1) estimate the numbers of Morro Bay kangaroo rats on public and private land; (2) provide detailed descriptions of the physical, floral, and faunal characteristics of all areas; and (3) review current development plans that may affect existing habitat or proposed habitat preserves.

Initially, it is imperative to determine the population status (i.e., current microdistribution and density) of the remaining Morro Bay kangaroo rat populations. A comprehensive survey, comprising visual and focused trapping effort over all occupied and potentially occupied habitat should be conducted as soon as individuals demonstrate surface activity. The extent of population assessment involving capture/mark/recapture methods will depend upon the number of individuals present. If, after removing the 100 animals needed for captive propagation (see task 131) there are still animals remaining in the wild, then capture/mark/recapture techniques could be used on those remaining in the field.

21 Estimate population size at all sites, particularly Morro Palisades and Los Osos Oaks State Preserve.

Because no new information has been collected recently, updating and intensifying population and distribution estimates is vital to recovery efforts. Data on population distribution and densities will aid in the assessment of alternative management options. Population assessment on the Morro Palisades property is contingent upon gaining access to the property (see task

31). All animals captured should be permanently marked with a subcutaneous passive integrated transponder (PIT) tag. Animals not taken for captive breeding should be released at the site of capture and followed using capture/mark/recapture techniques.

22 Collect tissues from new captures in capture/recapture studies and animals taken into captivity.

At a minimum, a tissue sample (e.g., hair, ear clip) will be taken from each individual upon initial capture for subsequent genetic analysis. When possible, a sample of blood will be collected for genetic analysis of blood protein groups (refer to task 1321).

23 Quantify environmental parameters around capture sites.

The current understanding of Morro Bay kangaroo rat habitat relationships is largely based on generalizations, assumptions, and extensions of results from other species. Few data have actually been collected from Morro Bay kangaroo rats and their habitat. Additional ecological data are essential for proper progress of the recovery effort.

Each precise point of capture for individual kangaroo rats, either single capture locations for animals removed for captive breeding or recapture sites for ongoing population studies, will be marked for quantification of habitat parameters. Vertical and horizontal aspects of the biotic and abiotic microhabitat should be measured. Such quantification will allow initial identification of the range of microhabitats used by the species. This procedure is particularly important because most of the habitat that is currently occupied is senescent (aging) and probably represents an incomplete spectrum of habitats that can support the species.

- 24 Monitor remaining wild populations using capture/recapture to provide demographic data (birth and death rates, recruitment, dispersal distance, density, rate of population change, etc.) for population viability analyses (refer to task 5).**

The trapping program should follow a protocol that can be repeated at appropriate intervals for monitoring population dynamics. Ideally, monthly sampling for a minimum of 5 years and then a continued annual sampling would yield insight into population dynamics and provide necessary input for ongoing population viability analyses. At a minimum, quarterly trapping for the first 5 years will be required. Capture/mark/recapture methods will establish a base of knowledge on density, age and sex structure, birth and death rates, recruitment, dispersal distance, and habitat use. Concurrent with these field studies, it is essential to develop a monitoring protocol similar to that established for Stephens' kangaroo rat (O'Farrell 1992). Specific, permanent monitoring plots are essential for annual monitoring of population trends; timing should coincide with the peak in reproductive recruitment. Trends in population growth can then be monitored in order to detect significant changes requiring immediate action to stabilize and enhance population growth.

- 25 Assess microhabitat use at the Morro Palisades and Los Osos sites by direct observation and experimentation; replicate habitat use studies developed using the Lompoc kangaroo rat.**

It is critical to establish the range of suitable habitat and identify optimal conditions for the establishment of a management program. A specific study to directly assess microhabitat use should be implemented at the Morro Palisades and Los Osos Oaks sites. This can be accomplished using direct observation as well as experimental procedures.

26 Determine the social structure and mating system from observations of free-ranging animals.

Simultaneous to a trapping effort, a behavioral study also should be initiated. Although some aspects of social interaction can be inferred from trapping, detailed observations on free-ranging kangaroo rats are essential. Determination of social structure and mating system is critical for proper management of the wild population and the captive breeding program. Likewise, an understanding of behavioral responses to predators and manipulated habitats will be crucial in developing reintroduction and habitat manipulation programs.

27 Synthesize and analyze habitat data and develop protocols for habitat manipulation and ongoing management programs for all historically occupied habitat. The goal is to optimize habitat conditions on all available parcels, consistent with the protection of other sensitive species

Synthesize the body of habitat use data and develop a management protocol. This program will evolve, building on an expanding data base. It is imperative to begin habitat manipulations, based on the current understanding of suitable habitat, on historically-occupied habitat (e.g., Pecho)(Roest 1973) so that sites will be available to accommodate translocation or introduction of captive stock, as these animals become available. Detailed discussions with Aryan Roest can assist in formulating a working model of the range in occupiable habitats. It is expected that the range of manipulation methods and the treatment protocol schedule will be periodically refined by the findings of the proposed population and habitat use studies on Morro Bay kangaroo rats and the surrogate species. As the data base expands, population viability analysis updates should be performed.

3 Develop a comprehensive habitat management plan for the Morro Bay kangaroo rat, and implement short-term and long-term management actions.

The Morro Bay kangaroo rat is currently in an extremely critical population crisis. Immediate action (e.g., supplemental feeding, habitat manipulation, small mammal population control, and predator control) is imperative since extinction is otherwise certain. These and the other measures outlined are required to stabilize the population and gain some control over its fate.

Development of a comprehensive habitat management plan assumes that enough wild animals will be available to develop a comprehensive understanding of Morro Bay kangaroo rat habitat relationships (outlined under task 2). A considerable amount of interagency effort has been directed toward habitat research, manipulation, and protection on State property at the Pecho site. The success of long-term Morro Bay kangaroo rat habitat management depends on ecosystem management. To be effective, ecosystem management requires, at the very least, a manageable and stable boundary between current and future developed areas and habitat. This concept could be integrated with long-term land use plans such as the proposed “Greenbelt” that would link Morro Bay State Park and Montana de Oro State Park via much of the remaining Morro Bay kangaroo habitat.

31 Identify and prioritize habitat acquisition needs.

It is imperative to obtain access to private property (preferably through conservation easements) to determine the number of remaining Morro Bay kangaroo rats, to stabilize the population, and to gain some control over its fate.

Since Morro Palisades may support the only extant Morro Bay kangaroo rat population, as well as important environmental conditions for species perpetuation, this parcel should be given the highest priority for acquisition. Habitat on private property adjacent to the Pecho site at Montana de Oro

State Park should also be given high priority. Both sites exhibit desirable management and enforcement characteristics, are large enough to support a modest subpopulation, and are surrounded by low to moderate densities of people.

32 Identify and gain access to dispersal corridors.

The utility of unprotected, narrow corridors should be carefully weighed against long-term utility of privately owned sites as well as the overall level of genetic variation among remaining Morro Bay kangaroo rats.

The most important corridors connect the largest, closest-together areas, such as between Pecho South and Hazard North. It is equally important to establish a corridor between the Pecho and Morro Palisades sites. Like the corridor between the two previous sites, this corridor would probably produce a peninsular effect. The shortest corridor between Pecho and Morro Palisades would pass north of Morro Palisades through private property, developed agricultural land, and eucalyptus groves. An alternative corridor to the south of Morro Palisades would be longer, but might have the advantage of having development only on one side. The southerly corridor could be substantially wider because there is a broader band of undeveloped land. An additional advantage of the latter corridor is that it would present a broader frontage along Pecho Road than the Northern corridor. Connecting Buckskin and Santa Ysabel with Morro Palisades and Pecho will be more difficult because of the intervening patchwork of development. It may be possible to extend the Santa Ysabel/Junior High sites to the south and east so that they are closer to Buckskin. Similarly, the link between Buckskin and Morro Palisades will be tenuous. The location and size of Los Osos Oaks Preserve is important and even a small, direct link between Los Osos Oaks Preserve and Morro Palisades would make dispersal to Buckskin more likely.

33 Restore or enhance habitat.

Restoration of disturbed sites is required to stabilize the population and gain some control over its fate. Areas denuded of plant cover or invaded by undesirable plant species will require intense rehabilitation. Specific restoration methodology will be based upon overall habitat objectives for each affected site. Habitat restoration objectives will likely include experimental manipulation of plant communities to a preferred stage of recovery from disturbance and preferred species composition, based on ecological information drawn from proposed population surveys, habitat surveys, and previous research. Any habitat restoration effort should be dynamic and incorporate information provided from ongoing research and management actions. Priority should be given to habitat now occupied by Morro Bay kangaroo rats at the Morro Palisades site. Restored or enhanced areas should be monitored through the habitat “recovery” period. Obviously, the litmus test of some manipulations will be the success or failure of Morro Bay kangaroo rat reintroductions in terms of long-term sustainability.

331 Incorporate management needs of other sensitive species.

Prior to extensive or intensive habitat manipulation, each treatment site must be surveyed for populations of sensitive animals and plants. Surveys should be conducted for endangered, threatened, rare, or candidate species such as the Morro shoulder band snail (*Helminthoglypta walkeriana*), the Morro manzanita (*Arctostaphylos morroensis*), the Indian Knob mountain balm (*Eriodictyon altissimum*), and the Moro blue butterfly (*Icaricia icarioides moroensis*). Measures to reduce impacts to these species could include avoiding, relocating, or restoring sensitive animal and plant populations.

332 Restore drastically disturbed habitat.

Restoration of potential Morro Bay kangaroo rat habitats degraded by human activities must be planned. Sites exhibiting suitable slope, exposure, soil type, plant species, small mammal species, etc. would be targeted first. Some of these areas include moderately large sites within the historic range that are now bordered by urban or commercial developments. High priority areas would be those that could be managed as permanent habitats or dispersal corridors.

333 Control exotic plants.

Areas invaded by undesirable species, such as *Carpobrotus edulis* (fig-marigold), *Ehrharta calycina* (veldt grass), *Conicosia pugioniformis* (an iceplant) and various annual grasses have probably suffered a reduced habitat potential for Morro Bay kangaroo rats. Exotic species control must be undertaken as an active, ongoing habitat maintenance program to promote recruitment of preferred native species.

334 Manipulate habitats.

Determine and implement effective and appropriate vegetation manipulation including, but not limited to prescribed fire, and manual or mechanical measures. Radical experimental manipulation (e.g., the use of heavy equipment) should initially be done on relatively small sites to assess its effects. Revegetation, whether natural or management enhanced, should promote a shift to preferred plant and animal community composition.

335 Control competitive and predatory species.

Certain native species such as the California ground squirrel may need to be eliminated or continually controlled in the managed areas. Feral animals, particularly domestic cats and dogs, are a management

problem in the area. Elimination of feral cats and dogs will be necessary as will the control of local, free-roaming, domestic cats. Education of local cat and dog owners on the impacts of their pets to Morro Bay kangaroo rats and their habitat also will be necessary. Although the red fox is not known to be present in the Morro Bay area now, it is a predatory species that appears to be expanding its range in the county and may require control in the future. Control of potentially competitive or predatory species must be initiated as another part of active, ongoing habitat maintenance.

336 Manage public access.

Public access to restored areas and areas that have been adversely affected by recreational use may need to be managed. Regulatory and interpretive signs may assist in controlling use and in educating the public on the sensitive nature of such sites. Complete exclusion of the public from any area is unlikely to be necessary.

34 Monitor habitat condition trends.

Monitoring provides a way of evaluating the efficacy of different management practices. Emphasis on evaluating the general utility of a management approach (as opposed to evaluating site-specific management needs) will streamline ongoing habitat management efforts. Sufficient documentation will be available to distinguish changes directly related to management from changes associated with plant and animal community succession or other facets of community dynamics.

341 Develop monitoring protocol and site assessment criteria.

The appropriate protocols for monitoring Morro Bay kangaroo rats, plant communities, competing small mammals, predators, listed species, candidate species, and species of concern should be described using standard field biology procedures. These protocols, data

analyses, and reporting formats should be compiled into a handbook, which should have sufficient detail to cover long term change in monitoring personnel.

Site assessment criteria should be developed to identify detrimental trends, undesirable conditions, and appropriate response actions. Guiding habitat management priorities and actions through a monitoring program is, overall, probably cheaper and more effective than simply applying a generic habitat management program.

342 Develop and update habitat maps.

Develop and update habitat maps containing detailed information on current and historic distribution patterns, topography, soil types, vegetation types, watersheds, site condition ratings, and possibly management history (i.e., applied management measures such as fire, exotic species control, selective native species management). Refer to tasks 2 and 35 for additional mapping requirements.

343 Monitor the recruitment and recovery of associated sensitive coastal dune scrub species.

Species with restricted ranges in the coastal dunes will likely undergo population decreases as development, land uses, and habitat conditions continue to change. The effects of specific management actions must be monitored to build a data base on habitat responses that can be used to guide the conservation of species that might otherwise become threatened or endangered in the future. It is not appropriate to recover one species in the coastal dune scrub at the expense of the rest of the local plants and animals.

35 Develop habitat management plans.

Sites will require management plans. These plans should contain historic information on each site that would clarify past trends in habitat condition (e.g., fragmentation, exotic species), habitat maps (task 342), maps showing past and present management and zoning history, if any, and maps showing potential future land use on-site as well as on adjacent land. Present or future public access to management areas may require monitoring to ensure that access does not impact management objectives. Management plan objectives, protocols, maps, etc. must be updated as new information becomes available.

351 Coordinate an interagency management plan.

Federal and State agencies should coordinate with the County of San Luis Obispo on the goals and objectives of the management plan or a Habitat Conservation Plan for Morro Bay kangaroo rats. Additional coordination should be carried out with the County Service Area - 9 (CSA-9) staff, private landowners, and other community organizations so that community planning activities may be anticipated and integrated with habitat management plans and actions.

352 Develop cooperative agreements with local, State, Federal, and private concerns.

Cooperative management agreements should be developed with the County of San Luis Obispo; State agencies such as the California Departments of Fish and Game, Parks and Recreation, Coastal Commission, and Coastal Conservancy; educational institutions such as the California State University System and the University of California System; and private interests such as landowners, property management and development firms, planning firms, biological consultants, conservation organizations, and resource planning organizations. One purpose of such agreements would be to develop

instruments such as easements, ecological preserves, and conservation plans to facilitate the collective recovery and enhancement of Morro Bay kangaroo rats, other listed species, candidate species, and species of concern in the vicinity of Morro Bay, Los Osos, and Baywood Park. Another purpose would be to develop equitable, long term land use designations in these areas. Additionally, the purpose of some agreements would be to form an advisory panel of experts to review the specific impacts and benefits of proposed Morro Bay kangaroo rat habitat management protocols on nontarget species sharing the same habitat. The goal would be to develop viable management strategies that would benefit all biological elements of the local coastal dune scrub ecosystem.

353 Identify preserve boundaries and potential dispersal corridors.

Preserve boundaries and potential dispersal corridors should be identified. Fragmented habitat occurring throughout the South Bay area may provide potential preserve sites. Certain corridors, such as Pecho to Morro Palisades and Morro Palisades to Los Osos Oaks State Preserve, may be suitable for the establishment of permanent dispersal corridors. Refer to task 32 for additional evaluation of preserve corridors.

354 Post regulatory and interpretive information.

Appropriate interpretive and regulatory signs should be placed strategically on public lands. It may be necessary to close some areas for habitat restoration, erosion control, Morro Bay kangaroo rat population enhancement, reintroductions, or other purposes. Portions of State land accessible to off-road vehicles should be closed to vehicles and fencing may be required to protect some rehabilitated sites. To realize maximum success it will be essential to coordinate management actions with landowners and the local community.

355 Develop maps representing past, present, and future land use and zoning.

Maps should be developed that indicate species decline by showing the extent of habitat alteration and land use changes over the past 30 to 50 years. These maps may serve to guide management-related decisions.

356 Develop maps that represent the synthesis of research analysis and indicate the actions and areas necessary for species recovery.

Such maps will indicate potentially threatened areas within the historic range, identify locations where further habitat fragmentation is likely, and identify potential or existing dispersal corridors.

4 Reintroduce captive-born Lompoc and Morro Bay kangaroo rats into the wild and translocate wild Lompoc and Morro Bay kangaroo rats.

Assessment of reintroduction, translocation, and habitat manipulation techniques on the surrogate species should provide the background of information needed to successfully carry out these actions with Morro Bay kangaroo rats. Specific goals include determination of the best methods to optimize habitat quality at release sites, development of the best methods for reintroduction and translocation, and monitoring the success of reintroduction and translocation attempts using the Lompoc kangaroo rat. Refer to task 3 for details of habitat management.

41 Remove resident Lompoc kangaroo rats and replace with captive-born or translocated Lompoc kangaroo rats into Lompoc kangaroo rat habitat.

This experiment will provide data on the success of introduced animals in areas known to be suitable, without the effects of intraspecific competition. An experimental approach that includes evaluation of techniques that have been successful with other *Dipodomys* species will be adopted. Since this set

of tasks will take several years, it is important to choose sites with assured long-term access. Animals removed from the wild might be translocated or incorporated into the captive-breeding program. Experiments should be designed to determine the optimal season, developmental age, and local conditions for best release results.

411 Release Lompoc kangaroo rats into suitable existing habitat.

Evaluate the success of experimental reintroductions and translocations under variable conditions of predation, competition, plant community structure, human disturbances, supplemental feeding, and protective burrows, shelters, etc. This information will be used to predict the optimal conditions for releasing Morro Bay kangaroo rats.

4111 Determine the necessity for food supplementation for released animals.

Monitor body condition of released animals and provide dietary supplements if necessary. Avoid using the seeds of invasive plants or plants that might otherwise pose future habitat management problems. Investigate the possibility of integrating food supplementation with habitat restoration goals to minimize competitor effects among the plants involved.

4112 Determine the necessity for providing artificial burrow systems, protective shelters, enclosures, and exclosures.

The presence of suitable burrow systems, protective shelters, enclosures, and exclosures at the time of release may affect the success of the reintroduction or translocation. Results of these experiments will be incorporated into procedures used during reintroduction and translocation of Morro Bay kangaroo rats.

4113 Control predation on reintroduced Lompoc kangaroo rats.

Determine the relative efficacy of barriers, predator removal, predator eradication, etc. in promoting high survivorship of released animals. Rank predators according to their contribution to kangaroo rat mortality and control the most serious predators first.

4114 Control competitor effects.

Determine relative efficacy of barriers, competitor removal, competitor eradication, etc. in promoting high survivorship of released animals. Monitor kangaroo rat-competitor interactions under field conditions. Investigate the effects of size of the release group on degree and severity of competition.

4115 Control human-caused impacts.

Many of the factors affecting Morro Bay kangaroo rats also affect Lompoc kangaroo rats. Loss of habitat to roads, buildings, agriculture, and other developments is considered the major factor contributing to the decline of the Morro Bay kangaroo rat. Increasing human populations have brought in a variety of exotic plants and animals, caused a shift in predator/prey relations, impacted natural fire frequency, and brought about significant fragmentation of historic habitat. Effective control of human-caused impacts must include the control of exotic species, habitat manipulation, including periodic fires, and abatement of habitat fragmentation, including protection and management of important and federally designated critical habitat as well as dispersal corridors. Additionally, domestic and feral animals, particularly cats and dogs, can significantly affect rodent populations. These and

other feral and domestic predators will require control in management areas that support Morro Bay kangaroo rats. Refer to task 3 for additional information on human related impacts.

412 Release the Lompoc kangaroo rat into restored, rehabilitated, or enhanced native habitat.

This experiment follows the same procedure as outlined for releases into suitable habitat as described under task 41. Results of this experiment will allow evaluation of habitat rehabilitation efforts with the surrogate species. Rehabilitation procedures that result in successful establishment of this surrogate species will be applied to habitat rehabilitation for Morro Bay kangaroo rats (task 42).

413 Evaluate the responses of the surrogate subspecies to habitat manipulations under natural and experimental field conditions.

To obtain information for a habitat use model to be used in a habitat manipulation program, replicated studies should be conducted on the nearest ecologically equivalent taxon, the Lompoc kangaroo rat. These studies should investigate both direct habitat use and the effects of habitat perturbation, simulating proposed manipulation methods for Morro Bay kangaroo rats. The design of these studies should allow an accurate comparison between the two taxa to determine the suitability of incorporating the entire data base into a Population Viability Analysis (see task 5). Information gained would also be used to guide such activities as supplemental feeding of the Morro Bay kangaroo rat during habitat manipulations.

414 Reintroduce captive-born or translocated Lompoc kangaroo rats without removing residents.

This experiment contributes more immediately to understanding the necessary steps and potential problems with attempting to enhance genetic diversity of wild populations. Because of the potential for resident-newcomer antagonism, it will be necessary to monitor competitive and social interactions. The procedures used in this experiment follow those outlined under task 411.

415 Provide long-term monitoring and assessment of the released Lompoc kangaroo rats.

The long-term utility of the various experimental procedures outlined in tasks 2 and 3 require long-term monitoring in the field. Such monitoring should include assessment of body condition, reproductive condition, habitat use, and burrow construction and use. Both live-trapping and radio-monitoring techniques will be required to collect these long-term data.

42 Reestablish captive-born Morro Bay kangaroo rats into the wild and translocate wild Morro Bay kangaroo rats. Techniques developed using Lompoc kangaroo rats will be applied to Morro Bay kangaroo rat, as described in tasks under 12, 13, and 41.

Successful reintroduction of captive born Morro Bay kangaroo rats is critical to the recovery of this subspecies, and it may take several years depending on the success in the initial release(s). It is important to choose sites with assured long-term access.

421 Release Morro Bay kangaroo rats into suitable habitat.

Using techniques developed with the Lompoc kangaroo rat (see task 41), reintroduce Morro Bay kangaroo rats into suitable habitat (see task 3 for habitat management).

422 Determine the necessity for food supplementation for released animals.

Monitor body condition of released animals and provide dietary supplements if necessary. Avoid using the seeds of invasive plants or plants that might otherwise pose future habitat management problems. Investigate the possibility of integrating food supplementation with habitat restoration goals to minimize competitor effects among the plants involved (see task 4111).

423 Determine the necessity for providing artificial burrow systems, protective shelters, enclosures, and exclosures.

The presence of suitable burrow systems, protective shelters, enclosures, and exclosures at the time of release may affect the success of the reintroduction or translocation. Results from task 4112 will be used to guide the use of these structures.

424 Control predation on reintroduced Morro Bay kangaroo rats.

Determine the relative efficacy of barriers, predator removal, predator eradication, etc. in promoting high survivorship of released animals. Rank predators according to their contribution to kangaroo rat mortality and control the most serious predators first (see task 4113).

425 Control competitors.

Determine relative efficacy of barriers, competitor removal, competitor eradication, etc. in promoting high survivorship of released animals. Monitor kangaroo rat-competitor interactions under field conditions. Investigate the effects of size of release group on degree and severity of competition (see task 4114).

426 Control human-caused impacts.

Effective control of human-caused impacts must include the control of exotic species, habitat manipulation, including periodic fires, and abatement of habitat fragmentation, including protection and management of important habitat and dispersal corridors. Additionally, domestic and feral animals, particularly cats and dogs, can exert a significant impact on rodent populations. These and other feral and domestic predators will require control in management areas that support Morro Bay kangaroo rats. Refer to task 3 for additional information on human related impacts.

427 Monitor reintroduced Morro Bay kangaroo rats.

The recovery of the Morro Bay kangaroo rat can only be assessed through long-term monitoring of the species in the wild. Such monitoring should include assessment of density, body condition, reproductive condition, habitat use, and burrow construction and use (see tasks under 2 and 3). Both live-trapping and radio-monitoring techniques may be required to collect these long-term data.

5 Conduct a population viability analysis for the Morro Bay kangaroo rat and evaluate recovery criteria.

An integral part of this recovery plan is the population viability analysis (PVA). The population viability analysis model estimates the probability of extinction by

considering random demographic and naturally occurring events. The population viability analysis, given particular scenarios and estimated population parameters, will allow the estimation of probabilities of extinction that may then be used to (1) guide management decisions in the implementation of specific alternatives of the recovery plan, (2) estimate the conditions under which the objective of this plan (reclassifying the Morro Bay kangaroo rat) would be reached, and (3) monitor the changing probability of extinction as the recovery plan is implemented and the population parameters change.

51 Conduct a population viability analysis.

Data collected in Population and Habitat Survey Assessment research (task 2), Captive Breeding and Management research (task 1), and Genetic Survey research (task 13) will provide the estimated population parameters to be used in the population viability analysis. It is imperative to understand the variation in each parameter. Data from Morro Bay kangaroo rats should be augmented with data from Lompoc kangaroo rats. Additionally, data from other kangaroo rat species will be used if no other data are available. Use of such data should only continue until comparable data have been collected for the Lompoc and the Morro Bay kangaroo rat.

52 Evaluate recovery alternatives.

Where possible, the consequences of major recovery plan alternatives should be evaluated using the population viability analysis. Such alternatives include, but are not limited to deciding (1) what proportion of the population should be brought into captivity; (2) when it is appropriate to start introducing captive animals; (3) what number and distribution of wild populations is best (particularly when the number is initially small); (4) what proportion of the population should be exchanged between captivity and the wild per generation to best manage gene flow; and (5) what sections, if any, of the historical habitat range are less important for reaching the recovery objectives. It will not be necessary to evaluate some alternatives if the predictions from applicable population genetics theory are explicit and more

conservative than that estimated from a population viability analysis. The recovery actions should be updated and modified as genetic information becomes available. Contradictory results, when weighted for their accuracy and precision, should lead to a modification of recovery actions based on those assumptions. Specifically, if Morro Bay kangaroo rat subpopulations are found to be genetically differentiated, all efforts should be made to incorporate that variation into the captive breeding program.

53 Estimate target population size for recovery objective.

The population viability analysis should be used to identify the conditions under which the recovery objective can be reached. Specific estimates must be made for the number of populations, their respective sizes, and required longevity necessary to meet the conditions for reclassification.

54 Evaluate progress toward recovery.

To monitor recovery action success and potential for future reclassification, the population viability analysis estimate for the probability of extinction should be updated as the effects of major recovery efforts become known. Population parameters will change as the recovery plan is implemented, which in turn will change the probability of extinction. Consequently, the importance of specific recovery plan alternatives will likely change as well. The evaluation of alternatives should be based on the conditions (and population viability analysis) at the time the choice is to be made and not on conditions (and population viability analysis) that existed sometime in the past.

6 Develop and implement a public outreach program.

Although there appears to be a deep aesthetic appreciation for the landscape in and around Morro Bay, few residents are aware of the number of sensitive species that occupy both wetland and upland habitats in the area. Increased public education should elevate public awareness and understanding of these fragile

resources.

61 Conduct education and interpretation programs.

Most local residents have probably heard of Morro Bay kangaroo rats, but many of these same people are probably not aware of the biology, ecology, extent of human-caused impacts, and imminent extinction status of this species. Education and interpretation of natural resources, particularly Morro Bay kangaroo rats, will be an important aspect of perpetuating the species as well as enhancing local appreciation and cooperation directed toward preserving unique and fragile habitat in the area. Education and interpretation may include State Park docent programs and regular releases of information to local media outlets and to organizations for inclusion in their newsletters, magazines, etc.

62 Encourage public involvement in recovery.

In a 1991 report from The Land Conservancy of San Luis Obispo County to the California Coastal Conservancy, a strong local interest was found for protecting open space, open space that contains wildlife, and agricultural and scenic resources. The report, fueled by the need to protect upland habitat, particularly that of the Morro Bay kangaroo rat, identifies a clear need for a greenbelt surrounding the south bay communities of Baywood Park and Los Osos. Implementation of such a greenbelt (which would define the permanent edge of the communities) will require the cooperation of landowners holding Morro Bay kangaroo rat habitat, responsible government agencies, and the affected communities. A vigorous involvement by public, private, local, and special interest groups may provide a level of action sufficient to prevent extinction of the Morro Bay kangaroo rat.

63 Conduct school programs.

In the future, as now, an important means of public enlightenment is the introduction of issues and challenges of preserving sensitive resources to

school science programs. An early understanding of our relationship to the land, native wildlife, and other natural resources will likely provide momentum for future management efforts and habitat protection.

7 Develop a funding program.

Nearly all aspects of Morro Bay kangaroo rat recovery (e.g., salaries and wages, laboratory facilities, captive breeding facilities, field facilities, habitat manipulation projects, lab and field equipment and supplies, land lease arrangements, land acquisition, overhead, etc.) have associated costs. Funding from Federal and State agencies will likely need to be augmented with monies from other sources.

Identify potential private sources that support conservation of sensitive resources (e.g., foundations, federations, societies, clubs, outdoor and recreation equipment suppliers, computer and software companies, biotechnology companies, and resource extraction companies).

LITERATURE CITED

- Baumgardner, G. D. and M. L. Kennedy. 1994. Patterns of interspecific morphometric variation in kangaroo rats (genus *Dipodomys*). J. Mamm. 75(1): 203-211.
- Best, T. L. 1993. Patterns of Morphologic and Morphometric Variation in Heteromyid Rodents. Pp. 197 - 235, in Biology of the Heteromyidae. (H. H. Genoways and J. H. Brown, eds.) Spec. Publ. No. 10, Amer Soc. Mamm. 719 pp.
- Boulware, J. 1943. Two new subspecies of kangaroo rats (genus *Dipodomys*) from southern California. Univ. Cal. Publ. Zool. 46(7): 391-396.
- Braun, S. E. 1985. Home range and activity patterns of the giant kangaroo rat, *Dipodomys ingens*. J. Mamm., 66: 1-12.
- Brown, J. H. and B. A. Harney. 1993. Population and Community Ecology of Heteromyid Rodents in Temperate Habitats. Pp. 618 - 651, in Biology of the Heteromyidae. (H. H. Genoways and J. H. Brown, eds.) Spec. Publ. No. 10, Amer Soc. Mamm. 719 pp.
- Congdon, J. D. 1971. Population estimate and distribution of the Morro Bay kangaroo rat. California Dept. of Fish and Game, Wildlife Management Branch Administrative Report No. 71-11. 13 pp.
- _____ and A. I. Roest. 1975. Status of the endangered Morro Bay kangaroo rat. J. Mamm. 56(3): 679-683.
- Dixon, J. 1918. Field notes of Morro Bay trip, San Luis Obispo and Monterey Counties, California. Museum of Vertebrate Zoology, University of California, Berkeley, CA.
- French, A. R. 1993. Physiological Ecology of the Heteromyidae: Economics of Energy and Water Utilization. Pp. 509 - 538, in Biology of the Heteromyidae. (H. H. Genoways and J. H. Brown, eds.) Spec. Publ. No. 10, Amer Soc. Mamm. 719 pp.
- Gambs, R. D. 1985. Small mammal census of two study plots on Montana de Oro State Park near Morro Bay, San Luis Obispo County, California. Interim Report, California Department of Parks and Recreation, Sacramento, CA. 23 pp.

Draft Revised Morro Bay Kangaroo Rat Recovery Plan

- _____. 1986a. Status of Morro Bay kangaroo rats on 3 study plots at the Bayview site in 1984 and 1985. Interim Report, U. S. Fish and Wildlife Service, Sacramento, CA. 29 pp.
- _____. 1986b. Effects of a controlled burn (October 24, 1984) on small mammal populations on plot TUVWX at the Pecho site: comparison of 1984 (pre-burn) data to 1985 (post-burn) data. Interim Report, U. S. Fish and Wildlife Service, Sacramento, CA. 29 pp.
- _____. 1986c. The effects of a proposed wastewater system in the communities of Los Osos and Baywood Park, California, on the endangered Morro Bay kangaroo rat (*Dipodomys heermanni morroensis*). Biological Assessment, San Luis Obispo County, CA. 26 pp.
- _____. 1986d. Small mammal population studies at the Pecho, Hazard, and Turri sites and the effects of habitat manipulation on small mammals at the Pecho site: 1983-1984. Final Report, U. S. Fish and Wildlife Service, Sacramento, CA. 165 pp.
- _____. 1986e. The effects of a prescribed burn (October 3, 1985) on small mammal populations occupying critical, Morro Bay kangaroo rat habitat at Montana de Oro State Park: Comparison of pre-burn data (1985) to post-burn data (1986). Final Report, California Department of Parks and Recreation, Sacramento, CA. 44 pp.
- _____. 1986f. Introduction of captive Lompoc kangaroo rats (*Dipodomys heermanni arenae*) into a protective enclosure on native habitat at "Dune Lakes" (San Luis Obispo County), California. Final Report, California Department of Fish and game, Sacramento, CA. 41 pp.
- _____. 1986g. I. Effects of habitat manipulation (brush clearing and prescribed burning) on small mammal populations at the Pecho site in 1985 and 1986: plots ABC, DEF, GHI, JKL, TUVWX, AABBBCCDDEE, and FFGGHHIIJJ; II. Population studies of Morro Bay kangaroo rats and other small mammals at the Bayview site in 1986: plots NOP, QRS, and KKLLMM; III. Trends in small mammal populations on 7 study plots at the Pecho site and 3 study plots at the Bayview site from 1983 to 1986. Interim Report, U. S. Fish and Wildlife Service, Sacramento, CA. 81 pp.
- _____. 1990. Small mammal inventory of the Los Osos Oaks State Preserve, San Luis Obispo County, California. U. S. Fish and Wildlife Service; P. O. # 114300-0-0794; Ventura, CA. 18 pp.

Draft Revised Morro Bay Kangaroo Rat Recovery Plan

- _____ and V. L. Holland. 1988. Ecology of the Morro Bay kangaroo rat (*Dipodomys heermanni morroensis*). Final Report, U. S. Fish and Wildlife Service; Contract # 14-16-0001-85154 NR, Sacramento, CA. 138 pp.
- _____ and A. R. Nelson. 1989. Introduction of captive Morro Bay kangaroo rats (*Dipodomys heermanni morroensis*) into an enclosure on critical habitat at Montana De Oro State Park. Final Report, Cal. Dept. of Fish and Game, Sacramento, CA. Contract # FG7568. 85 pp.
- _____ and A. R. Nelson. 1990. Introduction of captive Morro Bay kangaroo rats (*Dipodomys heermanni morroensis*) into an enclosure on critical habitat at Montana De Oro State Park. Final Report, Cal. Dept. of Fish and Game, Nongame Bird and Mammal Sec. rep., Job EW 88 XVIII-1. 38 pp.
- _____, F. X. Villablanca, and A. I. Roest. 1988. Estimating the breeding season of Morro Bay kangaroo rats. Poster presented at the 68th Annual Meeting of the Amer. Soc. of Mammalogists, June 1988, Clemson Univ., Clemson, SC.
- Hanes, T. 1977. Chaparral. in Terrestrial Vegetation of California. M. Barbour and J. Major eds. Wiley & Sons, New York. 1002 pp.
- Grinnell, J. 1922. A geographical study of the kangaroo rats of California. Univ. Calif. Publ. Zool. 24(1): 1-124.
- Holland, V. L. and D Keil. 1986a. California vegetation. El Corral Publications. San Luis Obispo, CA. 292 pp.
- _____ and _____. 1986b. An assessment of the impact of the installation of the proposed CSA 9 Wastewater Treatment Facility on the vegetation of the Los Osos-Baywood Park area, San Luis Obispo County, CA. 38 pp.
- Hoover, R. F. 1970. Vascular plants of San Luis Obispo County. Univ. Cal. Press. 350 pp.
- International Union for the Conservation of Nature (IUCN). 1971. Red data book vol. 1 (Mammalia). Survival Service Comm. Code No. MA/57/DIPOD/HEE/MOR.
- Jones, T. 1993. Social Systems of Heteromyid Rodents. Pp. 575 - 595, *in* Biology of the Heteromyidae. (H. H. Genoways and J. H. Brown, eds.) Spec. Publ. No. 10, Amer Soc. Mamm. 719 pp.

Draft Revised Morro Bay Kangaroo Rat Recovery Plan

- Kelt, D. A. 1988. *Dipodomys heermanni* in Mammalian Species No. 323. Amer. Soc. Mamm. pp. 1-7.
- Lewis, H. Patterns of Indian burning in California: ecology and ethnohistory. Anth. Pap. No. 1. Ballena Press, Ramona, CA. 101 pp.
- Lidberg, J. 1982. Morro dunes ecological reserve management plan. Calif. Dept. of Fish and Game.
- Matocq, M., F. X. Villablanca, C. Orrego, and J. Randall. Feb. 1995. A mtDNA study of museum specimens reveals low historic genetic diversity in the endangered Morro Bay Kangaroo Rat (*Dipodomys heermanni morroensis*). Annual Meeting, Western Section, The Wildlife Society. Santa Rosa, CA.
- Merriam, C. H. 1907. Descriptions of ten new kangaroo rats. Proc. Biol. Soc. Wash. 20:75-80.
- Munz, P. 1968. A California flora and supplement. Univ. Cal. Press. 1681 + 224 pp.
- Nowak, R. M. 1991. Walker's Mammals of the World. Johns Hopkins Univ. Press. 632-634 pp.
- O'Farrell, M. J. 1992. Establishment of a population monitoring program for the endangered Stephens' kangaroo rat. Trans. West. Sec., The Wildlife Society.
- Patton, J. L. and D. S. Rogers. 1993. Cytogenetics. Pp. 236 - 258, in Biology of the Heteromyidae. (H. H. Genoways and J. H. Brown, eds.) Spec. Publ. No. 10, Amer Soc. Mamm. 719 pp.
- Rathbun, G., J. Eliason, and N. Siepel. 1989. Morro Bay kangaroo rat breeding project interim report number 1. Annual Report to the U.S. Fish and Wildlife Service, 1989: 17 pp.
- Rathbun, G., J. Eliason, and N. Siepel. 1990. Morro Bay kangaroo rat breeding project final report. Annual Report to the U.S. Fish and Wildlife Service, 1990: 24 pp.
- Reichman, O. J. and M. V. Price. 1993. Ecological Aspects of Heteromyid Foraging. Pp. 539 - 574, in Biology of the Heteromyidae. (H. H. Genoways and J. H. Brown, eds.) Spec. Publ. No. 10, Amer Soc. Mamm. 719 pp.

Draft Revised Morro Bay Kangaroo Rat Recovery Plan

- Risser, R. 1975. A study of the taxonomic status of the Morro Bay kangaroo rat, *Dipodomys heermanni morroensis*. Spec. Prob. Report, Cal Poly St. Univ. Biol. Sci. / Roest. 9 pp.
- Risser, R. 1976. The taxonomy of *Dipodomys heermanni* and *Dipodomys agilis* in central California. M.S. Thesis, Cal Poly St. Univ., San Luis Obispo.
- Roberts, M. and W. F. Rall. 1991. Captive breeding of the endangered Morro Bay kangaroo rat *Dipodomys heermanni morroensis*. FY 1991 Annual Report. Interagency Agreement 14-16-0001-90546 between U. S. Fish and Wildlife Service, Ventura CA and National Zoological Park, Washington D. C. 77 pp.
- _____. and _____. 1993. Captive breeding of the endangered Morro Bay kangaroo rat *Dipodomys heermanni morroensis*. FY 1992 Annual Report. Interagency Agreement 14-16-0001-90546 between U. S. Fish and Wildlife Service, Ventura CA and National Zoological Park, Washington D. C. 85 pp.
- Roest, A. I. 1973. Morro Bay kangaroo rat habitat evaluation study. California Dept. of Fish and Game, Special Wildlife Investigations Progress Report, W-54-R. 25 pp.
- _____. 1977. Distribution and population estimate of the Morro Bay kangaroo rat, 1977. Report for Calif. Dept. of Fish and Game, Contract No. S1312, 19 pp.
- _____. 1982. Morro Bay kangaroo rat. in The IUCN Mammal Red Data Book, Part 1, J. Thornback and M. Jenkins (eds.), International Union for Conservation of Nature and Natural Resources, Gland, Switzerland, pp. 233-235.
- _____. 1984. The Morro Bay kangaroo rat: a summary of current knowledge. Poster presented at the 64th annual meeting of the Amer. Soc. of Mammalogists, June 1984, Humboldt State Univ., Arcata, CA.
- _____. 1988. Morro Bay kangaroo rat captive breeding program. Final Summary Report. U. S. Fish and Wildlife Service, Sacramento, CA.
- _____. 1989. Morro Bay kangaroo rat captive breeding program (The Absolutely Ultimate Final Report). U. S. Fish and Wildlife Service, Sacramento, CA.
- _____. 1991. Captive reproduction in Heermann's kangaroo rat, *Dipodomys*

Draft Revised Morro Bay Kangaroo Rat Recovery Plan

- heermanni*. Zoo Biol. 10: 127-137.
- Souza, L. 1958a. Distribution and abundance of the Edna kangaroo rat population. Senior Project, Cal Poly St. Univ., San Luis Obispo, CA. 18 pp.
- Souza, L. 1958b. Additional studies on kangaroo rats in western San Luis Obispo County. Special Problems, Cal Poly St. Univ., Biological Sciences Dept. / Roest. 4 pp. + map.
- Stewart, G. R. 1958. Notes on the Morro Bay kangaroo rat. Senior Project, Cal Poly St. Univ., San Luis Obispo, CA. 49 pp.
- _____ and A. I. Roest. 1960. Distribution and habits of kangaroo rats at Morro Bay. J. Mamm. 41(1):126-129.
- Thompson, K. 1993. Dyadic encounters of male and female *Dipodomys heermanni*. in Roberts, M. and W. Rall. 1993. Captive breeding of the endangered Morro Bay kangaroo rat *Dipodomys heermanni morroensis*. FY 1992 Annual Report. Interagency Agreement 14-16-0001-90546 between U. S. Fish and Wildlife Service, Ventura CA and National Zoological Park, Washington D. C. 85 pp.
- Toyoshima, J. M. 1983. Small mammal populations in a coastal sage scrub community. M. S. Thesis, Cal Poly St. Univ., San Luis Obispo, CA. 81 pp.
- U. S. Fish and Wildlife Service. 1982. Morro Bay kangaroo rat Recovery Plan. Prepared by A. I. Roest for USFWS, Portland OR. 69 pp.
- Villablanca, F. X. 1986. Morro Bay kangaroo rat distribution, status, population estimate, and habitat evaluation throughout their original range: August to September 1984 and April to August 1985. Interim Report, U. S. Fish and Wildlife Service, Sacramento, CA. 57 pp.
- _____. 1987. Distribution, status, and ecology of Morro Bay kangaroo rats and their habitat. Senior Project. Cal Poly St. Univ., San Luis Obispo, CA. 83 pp.
- Williams, D. F., D. J. Germano, and W. Tordoff III. 1992 (draft). Population studies of endangered kangaroo rats and blunt-nosed leopard lizards in the Carrizo Plain Natural Area, California. California Dept. of Fish and Game, Nongame Bird and Mammal Section Report, 92-0X. 113 pp.

Draft Revised Morro Bay Kangaroo Rat Recovery Plan

Williams, D. F., H. H. Genoways, and J. K. Braun. 1993. Taxonomy and Systematics. Pp. 38 - 196, *in* Biology of the Heteromyidae. (H. H. Genoways and J. H. Brown, eds.) Spec. Publ. No. 10, Amer Soc. Mamm. 719 pp.

Draft Revised Morro Bay Kangaroo Rat Recovery Plan

OTHER LITERATURE

- Blakesley, Andrea J. 1986. Breeding and behavior of kangaroo rats in captivity. Senior Project, Cal Poly St. Univ. San Luis Obispo, CA.
- Daniels, Alice G. 1979. Laboratory breeding of the kangaroo rat, *Dipodomys heermanni arenae*. Senior Project, Cal Poly St. Univ. , San Luis Obispo, CA.
- Gambs, R. D. 1989. The effects of fire on small mammals occupying critical Morro Bay kangaroo rat habitat at Montana De Oro State Park. Final Report, Cal. Dept. of Parks and Recreation, Monterey CA, Standard Agreement No. 84-04-276. 35 pp.
- Gularte, R. 1983. A small mammal trapping survey at Montana de Oro State Park. Senior Project, Cal Poly St. Univ., San Luis Obispo, CA. 64 pp.
- Gustafson, J. R. 1997. Job performance report, Morro Bay kangaroo rat - captive breeding. Job number EW96 XVIII-1. California Department of Fish and Game. September 23, 2 pp.
- Gustafson, K. 1984. A comparison of the vegetation and soils at the Pecho study area, Los Osos, CA. Senior Project, Cal Poly St. Univ. , San Luis Obispo, CA. 40 pp.
- Holland, V. L. 1986. A study of the vegetation on the Pecho and Bayview Morro Bay kangaroo rat study sites from 1982 to 1986, San Luis Obispo County, California. Interim Report. U. S. Fish and Wildlife Service, Sacramento, CA. 199 pp:
- _____ and D. Keil. 1984. Vegetation of the Morro Bay kangaroo rat Pecho study area. Interim Report. U. S. Fish and Wildlife Service, Sacramento, CA. 10 pp.
- _____ and _____. 1986. An assessment of the south bay wastewater treatment facility's groundwater recharge basins on the vegetation of site 6, Los Osos, CA, San Luis Obispo County, CA. 17 pp.
- Inman, S. 1983. Vegetation analysis of the Pecho study plots ABC, DEF, GHI, and JKL. Senior Project, Cal Poly St. Univ. , San Luis Obispo, CA. 45 pp.

Draft Revised Morro Bay Kangaroo Rat Recovery Plan

- Katson, K. and J. Hartshorn. 1984. A comparison of plots at the Pecho study site, Los Osos, CA. Senior Project, Cal Poly St. Univ. , San Luis Obispo, CA. 62 pp.
- Kenagy, J. L. 1973. Daily and seasonal patterns of activity and energetics in a heteromyid rodent community. *Ecology*, 54: 1201-1219.
- Kent, K. 1986. Quantitative vegetation survey and comparison of plots at the Pecho study site. Senior Project, Cal Poly St. Univ. , San Luis Obispo, CA. 60 pp.
- Kozik, C. 1977. Reproduction of the kangaroo rat, *Dipodomys heermanni arenae*, in captivity. Senior Project, Cal Poly St. Univ. , San Luis Obispo, CA. 30 pp.
- Larson, R. 1985. Habitat preference of small mammals in a coastal sage scrub community. Senior Project, Cal Poly St. Univ., San Luis Obispo, CA. 27 pp.
- Nelson, A. R. 1987. Effects of fire on small mammals living in critical Morro Bay kangaroo rat habitat at Montana De Oro State Park. Senior Project, Cal Poly St. Univ., San Luis Obispo, CA. 52 pp.
- Odegard, T. 1986. Qualitative vegetation analysis of the Bayview and Pecho Morro Bay kangaroo rat study sites. Senior Project, Cal Poly St. Univ., San Luis Obispo, CA. 60 pp.
- Rice, Karen. 1988. Captive breeding of *Dipodomys heermanni arenae* and the Endangered *Dipodomys heermanni morroensis*. Senior Project, Cal Poly St. Univ., San Luis Obispo, CA.
- _____. 1982. Morro Bay kangaroo rats. in CRC Handbook of Census Methods for Terrestrial Vertebrates, D. E. Davis (ed.), CRC Press. Boca Raton, Florida. pp. 171-172.
- Schneider, S. N. 1988. Effects of brush removal on small mammals living in critical Morro Bay kangaroo rat habitat at Montana De Oro State Park. Senior Project, Cal Poly St. Univ., San Luis Obispo, CA. 48 pp.
- Schroder, G. E. 1979. Foraging behavior and home range utilization of the bannertail kangaroo rat (*Dipodomys spectabilis*). *Ecology*, 60: 657-665.

Draft Revised Morro Bay Kangaroo Rat Recovery Plan

- Stickel, L. F. 1954. A comparison of certain methods of measuring ranges of small mammals. *J. Mamm.* 35(1): 1-15.
- Studley, M. A. 1978. *Dipodomys heermanni arenae*, the Nipomo mesa kangaroo rat, in a captive breeding colony. Senior Project. Cal Poly St. Univ., San Luis Obispo, CA. 28 pp.
- U. S. Fish and Wildlife Service. 1977. Determination of Critical Habitat for six endangered species. *Fed. Register* 42(11): 40685-40690, 11 Aug. 1977, Final Rule.
- Varsik, A. P. 1984. Breeding of *Dipodomys heermanni* in captivity. Senior Project. Cal Poly St. Univ. , San Luis Obispo, CA. 24 pp.
- Wacker, J. 1983. Notes on the vegetation of the Pecho study site with information relative to the endangered Morro Bay kangaroo rat. Senior Project. Cal Poly St. Univ. , San Luis Obispo, CA. 49 pp.
- Wood, N. 1985. Vegetation of plots ABC, DEF, GHI, JKL, and TUVWX of the Morro Bay kangaroo rat Pecho study area, Los Osos, CA. Senior Project. Cal Poly St. Univ. , CA. 68 pp.
- Zeeb, C. 1986. A vegetational analysis of the Pecho study site, Los Osos, CA. Senior Project. Cal Poly St. Univ. , San Luis Obispo, CA. 56 pp.

III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows is a summary of actions and estimated costs for this recovery program. It is a guide to meet the objective discussed in Part II of this plan. This schedule indicates the task priority, task numbers, task descriptions, duration of tasks, responsible agencies, and estimated costs. These actions will contribute to the recovery of the subspecies and protect its habitat. As the estimated monetary needs for all parties involved in recovery are identified, this schedule reflects the total estimated financial requirements for the recovery of this subspecies.

Priorities in the following implementation schedule are assigned as follows:

- 1 An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
- 2 An action that must be taken to prevent a significant decline in species' population or habitat quality, or some other significant negative impact short of extinction.
- 3 All other actions necessary to provide for full recovery of the species.

Parties Responsible for Implementation:

1. Fish and Wildlife Service (FWS)
2. California Department of Fish and Game (CDFG)
3. California State Parks (CSP)
4. University of California, Berkeley (UCB)
5. San Luis Obispo Land Conservancy (SLOLC)
6. County of San Luis Obispo (CLSO)
8. Recovery Team (RT)
7. Private landowners
8. California Polytechnic State University, San Luis Obispo (CPSU)

* denotes lead responsibility for the task.

Draft Revised Recovery Plan Implementation Schedule-Morro Bay kangaroo rat

Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars				
						2000	2001	2002	2003	2004
111	1	Continue captive breeding of Lompoc kangaroo rats at University of California, Berkeley.	On-going	FWS *CDFG UCB	240.0 70.0 300.0	60.0 15.0	60.0 15.0	60.0 15.0 50.0	60.0 15.0 50.0	10.0 50.0
112	1	Continue to conduct research on reproductive behavior of Lompoc kangaroo rats in captivity.	On-going	FWS *CDFG UCB	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111
113	1	Expand the number of captive breeding facilities for Lompoc kangaroo rats and Morro Bay kangaroo rats.	Continuous	*FWS CDFG UCB	unknown unknown unknown					
121	1	Develop and implement antipredator training for Lompoc kangaroo rats.	On-going	FWS *CDFG UCB	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111
122	1	Develop and implement foraging training for Lompoc kangaroo rats.	On-going	FWS *CDFG UCB	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111
123	1	Develop techniques for social training for Lompoc kangaroo rats.	On-going	FWS *CDFG UCB	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111
124	1	Ascertain the development of survival skills of Lompoc kangaroo rats.	On-going	FWS *CDFG UCB	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111	included in costs of Task 111

Draft Revised Recovery Plan Implementation Schedule-Morro Bay kangaroo rat

Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars				
						2000	2001	2002	2003	2004
131	1	Remove Morro Bay kangaroo rats from the wild.	3	FWS *CDFG UCB CPSU	60.0 15.0 unknown unknown	20.0 5.0	20.0 5.0	20.0 5.0		
1321	1	Conduct tissue sampling.	Periodic	FWS *CDFG *UCB	unknown unknown 3.0	1.0	1.0	1.0		
1322	1	Conduct mitochondrial DNA analyses on Morro Bay kangaroo rats.	3	FWS CDFG *UCB	45.0 unknown unknown	20.0	15.0	10.0		
1323	1	Survey historical mitochondrial DNA variation in Morro Bay kangaroo rats.	1	FWS CDFG *UCB	30.0 unknown unknown			30.0		
1324	1	Survey nuclear DNA variations in Morro Bay kangaroo rats.	3	FWS CDFG *UCB	35.0 unknown unknown	15.0	10.0	10.0		
1325	1	Conduct microsatellite DNA analysis on Morro Bay kangaroo rats.	3	FWS CDFG *UCB	45.0 unknown unknown	20.0	15.0	10.0		
1326	1	Survey genetic variation in Morro Bay kangaroo rat blood proteins.	1	FWS CDFG *UCB	10.0 unknown unknown			10.0		

Draft Revised Recovery Plan Implementation Schedule-Morro Bay kangaroo rat

Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars				
						2000	2001	2002	2003	2004
133	1	Conduct a captive breeding program for Morro Bay kangaroo rats.	Continuous	*FWS CDFG UCB	1,000.0 unknown unknown		60.0	80.0	80.0	80.0
134	1	Establish at least two additional captive populations of Morro Bay kangaroo rats.	Continuous	*FWS CDFG UCB	1,000.0 unknown unknown			60.0	80.0	80.0
141	1	Gather biological data from captive Morro Bay kangaroo rats.	Continuous	FWS CDFG *UCB	included in costs of Task 133	included in costs of Task 133	included in costs of Task 133	included in costs of Task 133	included in costs of Task 133	included in costs of Task 133
142	1	Train Morro Bay kangaroo rats for reintroduction.	Continuous	*FWS CDFG UCB	included in costs of Task 133	included in costs of Task 133	included in costs of Task 133	included in costs of Task 133	included in costs of Task 133	included in costs of Task 133
15	1	Secure access to Morro Bay kangaroo rats and their habitat on private lands.	10	*FWS CDFG SLOLC	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown
21	1	Estimate the population size of all remaining wild Morro Bay kangaroo rats populations.	1	*FWS CDFG	10.0 unknown	10.0				
22	1	Collect tissues from newly captured Morro Bay kangaroo rats.	Periodic	FWS CDFG *UCB	1.0 unknown unknown					1.0
23	1	Quantify environmental parameters around capture sites.	3	*FWS CDFG	20.0 unknown	10.0	5.0	5.0		

Draft Revised Recovery Plan Implementation Schedule-Morro Bay kangaroo rat

Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars				
						2000	2001	2002	2003	2004
24	1	Monitor remaining wild populations.	10	*FWS CDFG	unknown unknown	unknown unknown	unknown unknown	unknown unknown	unknown unknown	unknown unknown
25	1	Assess microhabitat use at Morro Palisades and Los Osos Oaks.	5	*FWS CDFG	25.0 10.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0
26	1	Determine the social structure and mating system of any remaining wild Morro Bay kangaroo rats.	5	*FWS CDFG	25.0 10.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0
27	1	Synthesize data and develop habitat management protocols.	On-going	*FWS CDFG CSP	15.0 5.0 unknown	5.0 2.0	5.0 2.0	5.0 2.0		
31	1	Identify and prioritize habitat acquisition needs.	On-going	*FWS CDFG	unknown unknown	unknown unknown	unknown unknown	unknown unknown	unknown unknown	unknown unknown
32	1	Identify and gain access to dispersal corridors.	On-going	*FWS CDFG SLOLC	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown
331	3	Incorporate management needs of other sensitive species.	On-going	*FWS CDFG CSP	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown
332	1	Restore drastically disturbed habitat.	3	*FWS CDFG CSP	150.0 60.0 90.0	50.0 20.0 30.0	50.0 20.0 30.0	50.0 20.0 30.0		

Draft Revised Recovery Plan Implementation Schedule-Morro Bay kangaroo rat

Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars				
						2000	2001	2002	2003	2004
333	1	Control exotic plants.	Continuous	FWS CDFG *CSP	50.0 unknown 50.0			10.0		
334	1	Manipulate habitat.	Every 5 years	FWS CDFG *CSP	150.0 60.0 90.0		50.0 20.0 30.0			
335	1	Control competitive and predatory species.	Periodic	FWS CDFG *CSP	20.0 5.0 15.0			8.0 2.0 5.0		
336	1	Manage public access.	Continuous	FWS CDFG *CSP SLOLC	unknown unknown unknown unknown	unknown unknown unknown unknown	unknown unknown unknown unknown	unknown unknown unknown unknown	unknown unknown unknown unknown	unknown unknown unknown unknown
341	1	Develop monitoring protocol and site assessment criteria.	1	*FWS CDFG CSP	unknown unknown unknown					
342	1	Develop and update habitat maps.	On-going	FWS CDFG *SLOLC	unknown unknown 10.0	10.0				
343	1	Monitor the recruitment and recovery of coastal dune scrub species.	Continuous	FWS CDFG *CSP	20.0 5.0 10.0		2.0 0.5 1.0	2.0 0.5 1.0	2.0 0.5 1.0	2.0 0.5 1.0

Draft Revised Recovery Plan Implementation Schedule-Morro Bay kangaroo rat

Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars			
						2000	2001	2002	2003
351	1	Coordinate an interagency management plan.	Continuous	*FWS CDFG SLOLC	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown
352	1	Develop cooperative agreements with State, Federal, local, and private concerns.	Continuous	*FWS CDFG SLOLC	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown
353	1	Identify preserve boundaries and potential dispersal corridors.	On-going	FWS CDFG *SLOLC	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown	unknown unknown unknown
354	1	Post regulatory and interpretive information.	1	*FWS CDFG CSP	unknown unknown 5.0			5.0	
355	1	Develop land use and land zoning maps.	1	FWS CDFG *SLOLC	unknown unknown 5.0				
356	1	Develop maps that identify areas for recovery.	On-going	*FWS CDFG SLOLC	5.0 unknown unknown	2.0		1.0	1.0
411	1	Remove resident Lompoc kangaroo rats and release captive born or translocated Lompoc kangaroo rats into suitable existing habitat.	1	FWS *CDFG UCB	5.0 unknown unknown		5.0		

Draft Revised Recovery Plan Implementation Schedule-Morro Bay kangaroo rat

Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars				
						2000	2001	2002	2003	2004
4111	1	Determine necessity for food supplementation for released Lompoc kangaroo rats.	3	FWS *CDFG	3.0 unknown		1.0	1.0	1.0	
4112	1	Determine the necessity for providing artificial burrows for released Lompoc kangaroo rats.	3	FWS *CDFG	3.0 unknown		1.0	1.0	1.0	
4113	1	Control predation of reintroduced Lompoc kangaroo rats.	3	FWS *CDFG	9.0 unknown		3.0	3.0	3.0	
4114	1	Control competitors of reintroduced Lompoc kangaroo rats.	3	FWS *CDFG	9.0 unknown		3.0	3.0	3.0	
4115	1	Control human-caused impacts to reintroduced Lompoc kangaroo rats.	3	FWS *CDFG	10.0 unknown		5.0	3.0	2.0	
412	1	Release Lompoc kangaroo rats into enhanced habitat.	3	FWS *CDFG	80.0 unknown	30.0	30.0	20.0		
413	1	Evaluate the response of reintroduced Lompoc kangaroo rats to habitat manipulations.	3	FWS *CDFG	6.0 3.0		2.0 1.0	2.0 1.0	2.0 1.0	
414	1	Reintroduce captive-born Lompoc kangaroo rats without removing resident LKR.	3	FWS CDFG	6.0 3.0		2.0 1.0	2.0 1.0	2.0 1.0	

Draft Revised Recovery Plan Implementation Schedule-Morro Bay kangaroo rat

Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars			
						2000	2001	2002	2003
415	1	Monitor reintroduced Lompoc kangaroo rats.	5	FWS CDFG	40.0 10.0		8.0 2.0	8.0 2.0	8.0 2.0
421	1	Release captive born Morro Bay kangaroo rats into the wild.	Continuous	FWS *CDFG	20.0 5.0		5.0 1.0	5.0 1.0	5.0 1.0
422	1	Determine the necessity for food supplementation for reintroduced Morro Bay kangaroo rats.	3	FWS *CDFG	3.0 unknown		1.0	1.0	1.0
423	1	Determine the necessity for providing artificial burrows for reintroduced Morro Bay kangaroo rats.	2	FWS *CDFG	2.0 unknown		1.0	1.0	
424	1	Control predation of reintroduced Morro Bay kangaroo rats.	10	FWS *CDFG	90.0 unknown		9.0	9.0	9.0
425	1	Control competitors of reintroduced Morro Bay kangaroo rats.	10	FWS *CDFG	90.0 unknown		9.0	9.0	9.0
426	1	Control human-caused impacts to reintroduced Morro Bay kangaroo rats.	10	FWS *CDFG	100.0 unknown		10.0	10.0	10.0

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Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars				
						2000	2001	2002	2003	2004
427	1	Monitor reintroduced Morro Bay kangaroo rats.	10	FWS	100.0			10.0	10.0	10.0
51	2	Conduct population viability analysis.	1	*FWS	100.0			5.0	5.0	5.0
52	2	Evaluate recovery alternatives.	Continuous	*FWS	unknown	unknown	unknown	unknown	unknown	unknown
53	1	Estimate the target population size for recovery objectives.	Continuous	*FWS	unknown	unknown	unknown	unknown	unknown	unknown
54	2	Evaluate progress towards recovery.	Continuous	*FWS	unknown	unknown	unknown	unknown	unknown	unknown
61	2	Conduct interpretation and education programs.	Continuous	*FWS	unknown	unknown	unknown	unknown	unknown	unknown
				SLOLC	unknown	unknown	unknown	unknown	unknown	unknown
				CSP	unknown	unknown	unknown	unknown	unknown	unknown
62	1	Encourage public involvement in recovery.	Continuous	*FWS	unknown	unknown	unknown	unknown	unknown	unknown
				CDFG	unknown	unknown	unknown	unknown	unknown	unknown
				SLOLC	unknown	unknown	unknown	unknown	unknown	unknown
				CSP	unknown	unknown	unknown	unknown	unknown	unknown
63	2	Conduct school programs.	Continuous	*FWS	unknown	unknown	unknown	unknown	unknown	unknown
				SLOLC	unknown	unknown	unknown	unknown	unknown	unknown
				CSP	unknown	unknown	unknown	unknown	unknown	unknown

Draft Revised Recovery Plan Implementation Schedule-Morro Bay kangaroo rat

Task Number	Priority Number	Task Description	Task Duration	Responsible Party	Total Cost to Recovery	Costs, by fiscal year, thousands of dollars				
						2000	2001	2002	2003	2004
70	1	Develop a funding program.	Continuous	*FWS CDFG SLOLC CCC	unknown unknown unknown unknown	unknown unknown unknown unknown	unknown unknown unknown unknown	unknown unknown unknown unknown	unknown unknown unknown unknown	unknown unknown unknown unknown
TOTALS						344	496.5	629.5	379.5	298.5

4,521*

* The total cost of recovery is estimated to be \$4,521,000 plus additional costs that are unknown at this time.

APPENDIX 1: SYSTEMATICS AND ECOLOGY OF THE MORRO BAY KANGAROO RAT

Systematics:

Williams et al. (1993) provide a recent review of the taxonomy of the rodent family Heteromyidae. Members of the genera *Dipodomys* (kangaroo rats) and *Microdipodops* are both classified in the subfamily Dipodomyinae because of similarities in muscular, skeletal, phallic, and auditory systems as well as patterns of protein electrophoresis (Williams et al. 1993). Dipodomyinae have a ricochetal body form, densely haired soles of the hind feet, and greatly enlarged, hollow mastoid bullae that form more than half of the dorsal surface of the skull posterior to the orbits (Williams et al. 1993). Compared with *Microdipodops*, members of the genus *Dipodomys* are larger (total length = 205 to 370 millimeters [8.1 to 14.6 inches]); have proportionately longer tails (about 1.05 to 1.6 times the length of head and body) that taper evenly to a tip having long hairs that form a distal crest and tuft; either lack, externally, digit 1 of the hind foot or have only a vestige of digit 1 located about half-way up the hind foot; and have auditory bullae that are not as greatly inflated anteriorly and dorsally (Williams et al. 1993).

In a discriminant-function analysis of morphometric variation among 19 species of *Dipodomys*, Baumgardner and Kennedy (1994) found that both male and female *D. californicus*, *D. elator*, *D. heermanni*, *D. panamintinus*, *D. stephensi*, and perhaps *D. venustus* occupied similar morphometric space and appear to form a species group. Male *D. microps* and female *D. agilis* also appeared to belong to this same species group.

Best (1993), using multivariate correlation and distance matrix analyses, examined morphological variation among 57 species of heteromyid rodents. Phenograms constructed from distance matrices of 21 species of *Dipodomys* showed that both male and female *D. agilis*, *D. californicus*, *D. heermanni*, *D. panamintinus*, and *D. stephensi* form a closely related group. *D. elator* and *D. gravipes* form a separate cluster that is in turn closely related to the group formed by the first five species. Unlike the results of Baumgardner and Kennedy (1994),

results of Best (1993) show *D. venustus* and *D. microps* to be less similar to the first seven species. Phenograms constructed from distance matrices of all 57 species of heteromyid rodents showed that both male and female *D. californicus*, *D. heermanni*, *D. panimintinus*, and *D. stephensi* form a closely related group and *D. elator* and *D. gravipes* form an adjacent cluster closely linked to the first four species (Best 1993). Interestingly, *D. agilis* females grouped with the *D. californicus*, *D. heermanni*, *D. panimintinus*, and *D. stephensi* cluster, but *D. agilis* males were in a different cluster.

Five presumptive groups of *Dipodomys* are recognized on the basis of karyotypic and morphological variation (Patton and Rogers 1993). The *heermanni* group includes *D. deserti*, *D. microps*, *D. elephantinus*, *D. venustus*, *D. agilis*, *D. ingens*, *D. heermanni*, *D. panamintinus*, *D. californicus*, *D. stephensi*, and *D. gravipes*, species having a diploid chromosome number ranging from 52 to 70 and an autosomal arm number ranging from 71 to 116. Clarification and greater understanding of *Dipodomys* systematics should accompany additional analyses of cytogenetic systems at the level of molecular genomic characterization (Patton and Rogers 1993).

Heermann's kangaroo rat (*Dipodomys heermanni*), 1 of 12 species with 5 clawed-toes on the hind foot, is similar in size and general appearance to the contiguous species *D. agilis* and *D. venustus* and the allopatric species *D. stephensi* and *D. gravipes* (Williams et al. 1993). Compared with *D. agilis*, *D. venustus*, and *D. elephantinus*, *D. heermanni* has smaller ear pinnae, lighter coloration, a less heavily crested tail, and a broader face across the maxillary arches. Compared with *D. gravipes*, *D. heermanni* has shorter hind feet. Compared with *D. stephensi*, *D. heermanni* has a less globular auditory bullae and proportionally longer tail. Compared with the sympatric species *D. nitratoides*, *D. heermanni* is much larger (about twice as heavy) and has five rather than four hind toes. Compared with the sympatric species *D. ingens*, *D. heermanni* is about two-thirds as heavy, has shorter hind feet (less than 45 millimeters [1.8 inches]), and has a relatively longer tail (Williams et al. 1993).

The species *Dipodomys heermanni* includes nine subspecies: *D. h. arenae*,

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berkeleyensis, *dixonii*, *goldmani*, *heermanni*, *jolonensis*, *morroensis*, *swarthi*, and *tularensis*. They inhabit the inland valleys and coastal plains of California from south of the American River on the east and the Suisun Bay on the west, southward, below 900 meters (3,000 feet) elevation to Point Conception and the Tehachapi Mountains (Kelt 1988, Williams et al. 1993) (Figure 1).

The Morro Bay kangaroo rat differs from its most similar taxa and geographical neighbors in its smaller size and darker coloration (Appendix 2). Merriam (1907) felt these features were sufficient to warrant full species status, and described the Morro Bay animals as *Perodipus morroensis*. Grinnell (1922) supported this recognition, but revised the name to *Dipodomys morroensis*. Boulware (1943) however, noted its resemblance to Heermann's kangaroo rat, and named it as a subspecies of that species, *Dipodomys heermanni morroensis*. Other more recent studies have confirmed its distinctive features and its relationship to *D. heermanni* (Risser 1975, 1976; Roest 1984).

The isolation of the Morro Bay kangaroo rat from other subspecies of *Dipodomys heermanni* is complete. Souza (1958a, 1958b) found the nearest populations of *D. h. arenae* about 22.5 kilometers (14 miles) southeast and 1.6 kilometers (1 mile) west of Edna, where an isolated colony occupies about 142 hectares (350 acres). The Edna population is a range extension for *D. h. arenae*, which is otherwise found south from Arroyo Grande to Point Conception (Boulware 1943). *D. h. jolonensis*, which occurs from approximately Atascadero northward, ranges to within roughly 27.4 kilometers (17 miles) of the range of *D. h. morroensis*. *D. h. swarthi* only occurs in the eastern part of San Luis Obispo County and is separated from *D. h. morroensis* by over 64.4 kilometers (40 miles).

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APPENDIX 2: Average morphometric values and coloration that distinguish *Dipodomys heermanni morroensis* from adjacent subspecies (geographically and taxonomically). M/F=male/female; n=number of specimens. Source: Grinnell 1922, Roest 1984.

Features:	Subspecies:			
	<i>D. heermanni jolonensis</i>	<i>D. heermanni swarthi</i>	<i>D. heermanni arenae</i>	<i>D. heermanni morroensis</i>
Mean and	304	297	301	293
Range of	295-313	288-319	281-315	269-320
Total Length (mm)*	(n=10)	(n=11)	(n=20)	(n=80)
Mean and	188	179	176	174
Range of	175-200	170-193	162-185	152-175
Tail Length (mm)	(n=10)	(n=11)	(n=20)	(n=80)
Mean and	87.7	87.0	68.8	64.5
Range of	79-94	80-95	61-82	56-81
Total Weight (grams) #	(n=10)	(n=2)	(n=20)	(n=62)
Mean and	41.1/39.6	40.4/40.1	39.7/38.7	38.5/38.3
SD of M/F	0.93/1.46	1.27/0.61	1.21/0.60	0.98/0.31
Skull Length (millimeters)	(n=14/11)	(n=5/4)	(n=19/7)	(n=14/7)
Mean and	22.7/22.1	22.0/22.3	21.7/21.2	21.9/21.7
SD of M/F	0.63/0.76	1.13/0.87	0.79/.87	0.56/0.52
Maxillary Width (millimeters)	(n=13/11)	(n=5/4)	(n=19/7)	(n=14/7)
Dorsal Color	light	pale	medium	dark

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Hip Stripe	present in 100 percent of specimens	present in 100 percent of specimens	present in 95 percent of specimens	present in less than 25 percent of specimens
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*10 millimeters (mm) = 2.54 inches. #100 grams (g) = 3.5 ounces